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Measuring and Comparing the Cost-Effectiveness  
of EPA Regulatory Efforts to Control  
Toxics-Related Health Risks. Volume II  
Cost-Effectiveness Analysis of EPA Intermedia  
Priority Pollutants

ICF, Inc.  
Washington, DC

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MEASURING AND COMPARING THE COST-EFFECTIVENESS OF  
EPA REGULATORY EFFORTS TO CONTROL TOXICS-RELATED  
HEALTH RISKS--VOLUME II, COST-EFFECTIVENESS  
ANALYSIS OF EPA INTERMEDIA PRIORITY POLLUTANTS

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| 15. Abstract (Limit: 200 words) The Office of Toxics Integration of the Environmental Protection Agency undertook this study to examine the conceptual and practical limitations of the application of traditional cost-effectiveness methods to multi-media regulatory analysis and to determine the extent to which these methods may contribute to the integration of EPA's multiple program office controls on toxic chemicals.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |  |                                   |  |                                                          |  |
| <p>The goal in developing inter-media air, land, and water cost-effectiveness analysis is to allow comparative evaluation of the various combined alternatives for chemical risk reduction. The key analytical problem in developing an integrated approach is the difficulty of comparing the relative costs and benefits of regulatory proposals (or existing regulations) across media. Conventional benefit measures are usually not feasible to support a multi-media chemical control strategy. Benefit measures must reflect some positive change that is closer in the chain of effects to the ultimate receptors, e.g., units of exposure reduced or specific health risks reduced, than has generally been reflected in past regulations. The study also demonstrates the difficulties in comparing cost data between different Agency control programs.</p> <p>Volume II analyzes specific regulations in order to add substance to the concepts and principles discussed in Volume I and also to begin collection of baseline data which will provide a frame of reference for future analyses.</p> |  |                                   |  |                                                          |  |
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## FOREWORD

The Office of Toxics Integration (OTI) began this study of cost-effectiveness analysis with several objectives in mind. First, it was important to determine the extent to which traditional cost-effectiveness methods might be used to contribute to OTI's inter-media integration responsibilities for chemicals. Second, in view of the rather unique character of an integrated or multi-media regulatory analysis, some of the conceptual as well as practical limitations of most cost-effectiveness analytical practices available to the Agency were already evident. Thus, this study was designed to explore ways to bridge those limitations, to develop several innovative techniques and concepts, and (in cases where the limitations may be problematic) to get a better understanding of the implications for multi-media analysis.

OTI's mission is to integrate the EPA program offices' activities with respect to toxic chemicals of multi-media interest. A major part of that responsibility is to develop integrated, Agency-wide strategies for toxic substances problems occurring in more than one medium. In general, the primary objectives of an integrated EPA control strategy are to minimize inadvertent transfers of a toxics chemical problem from one medium to another and to maximize the combined (i.e., all media taken together) regulatory benefits and minimize the combined regulatory costs. Because an integrated strategy specifically considers all media and regulatory options, controls can be designed to take advantage of variances across media in exposure levels, costs of control, etc. At the same time, an integrated approach allows OTI to determine the net effects of all controls and to evaluate the implications of transfers of toxics from one medium to another.

When viewed as a whole, a set of regulatory proposals representing each EPA program office's effort to control a substance in each medium reflects certain objectives regarding benefits and costs. OTI's goal in developing inter-media cost-effectiveness analysis is to allow comparative evaluation of combined alternatives for chemical risk reduction. The key analytical problem in developing an integrated approach, however, is the difficulty of comparing the relative costs and "benefits" of regulatory proposals (or existing regulations) across media.

Cost-effectiveness analysis is traditionally viewed as an appropriate analytical technique for identifying least-cost ways of achieving a given objective, or for maximizing the benefits for a given cost. However, most examples of cost-effectiveness analysis in the Agency have been used in a single medium context (e.g., cost-effectiveness comparisons of alternative control technologies in air). Because these analyses are somewhat narrow in focus and single-media in context, conventional benefit measures such as "pounds of pollutant emissions controlled" may be adequate for single-media analytical requirements.

However, because of the broad scope and objectives of an inter-media analysis, conventional benefit measures are usually not sufficient for inter-media cost-effectiveness analysis. To the extent that OTI's cost-effectiveness analyses support a multi-media control strategy, benefit measures must reflect some positive change that is closer in the chain of effects to the ultimate receptors. By considering and using measures such as units of exposure reduced, or even specific health risks reduced, an integrated control strategy based on an inter-media cost-effectiveness analysis can take advantage of the likely variation across media in the cost of control per exposure reduced, health risk reduced, etc.

At the same time, this study demonstrates the difficulties in comparing cost data between different control programs. For example, inconsistencies arising out of differences in cost models used, or simply the ways in which costs are categorized, present analytical and practical problems for a multi-media cost-effectiveness analysis. This study highlights some of these problems and identifies some candidate solutions for them.

The first part of this study is a discussion of some of the major analytic principles that are the basis for the subsequent analyses. This part also contains a discussion of the major conceptual and practical problems in applying these concepts.

The remainder of the document, including the second volume, comprises a series of case studies. In Volume I, these are less detailed, pilot case studies. Volume II contains a more in-depth approach designed to add substance to some of the concepts and principles discussed earlier.

The regulations studied in the course of this work were chosen primarily to highlight the analytical issues, but also to begin collection of baseline data which will provide a frame of reference for future analyses.

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## 1. INTRODUCTION

EPA's Office of Toxics Integration (OTI) was created to address the need for communication and coordination among EPA offices, and to expand and improve existing regulatory efforts by developing an integrated approach to toxic substance control that would achieve the most effective and efficient results feasible. This mission involves analyzing the statutes and statutory authorities, and intermedia effectiveness of various types of regulatory strategies and standards. In all of these instances, it is necessary to discern the relative cost-effectiveness of particular toxic substance control options.

OTI requires an analysis framework and techniques to ensure effective control of toxic risks throughout EPA and other federal agencies. The statutory authority for controlling various risks is fragmentary and often inconsistent. Not only do new legislative initiatives and existing statutes require close examination to rectify gaps, overlaps, and inconsistencies, but the regulatory controls themselves need to be examined. An unbiased method of analysis that can be applied to the wide variety of existing and expected regulatory controls is needed to help rationalize priorities for regulation. Cost-effectiveness analysis is one such heuristic method.

Cost-effectiveness analysis can be a valuable input to the regulatory decision-making process. Although its use will not necessarily provide "the answer," cost-effectiveness analysis requires rigorous examination of the underlying assumptions of contemplated actions and/or existing controls. The methodology results in a thorough identification of the likely costs and benefits of a policy over its life and provides a basis for evaluating who will enjoy the benefits and which parties bear the costs. Furthermore, it allows for the identification of those options which, on the basis of the cost-effectiveness criterion, are preferred. Therefore, cost-effectiveness analysis, as an important component of a toxics integration strategy, can be valuable for:

- comparing the effectiveness of alternative methods of regulatory control;
- assessing the extent to which a given substance or substances should be controlled in the various media;
- reviewing and updating existing regulations to ensure that the maximum benefit is received for a given regulatory cost; and
- targeting regulatory activities into the most needed areas.

There are various informational and methodological barriers to successfully completing cost-effectiveness analyses for many existing EPA regulations. Therefore, OTI structured our analysis of the cost-effectiveness of EPA toxics-related regulatory efforts to begin with a feasibility study.<sup>1</sup> The feasibility study reviewed the availability of needed cost and effectiveness data, analyzed methodological issues potentially confounding to the successful accomplishment of a cost-effectiveness analysis, and performed case studies of five EPA toxics regulations in order to further study the effectiveness and cost issues and to develop a methodology for further cost-effectiveness analyses.

The feasibility study concluded that a cost-effectiveness analysis of EPA toxics regulations was feasible and could produce interesting, useful results. The analysis indicated that a substantial amount of data collection and analysis would usually be required to develop the necessary cost and effectiveness estimates and that the approach taken should utilize existing data and accepted assumptions as much as possible.

With the feasibility of the use of cost-effectiveness analysis for EPA toxics regulations determined, the next phase of the project involved studying the cost-effectiveness of various EPA toxics regulations. This was divided into two parts. One part involved analyzing the cost-effectiveness of a series of regulations concerning a group of six priority chlorinated solvents. The objective of this work was to review the availability of cost and effectiveness data for the specific regulations, to identify problems in analyzing the cost-effectiveness of these regulations, and to calculate the cost-effectiveness of these regulations when possible. The report of that work is available as a separate document.

The other part of the second phase is described in this report. It involves analysis of the cost-effectiveness of regulations of a series of chemicals identified by EPA as Intermedia Priority Pollutants. The pollutants represent a consensus view of the various EPA programs involved in developing or implementing toxic pollutant regulations. Intermedia Priority Pollutants are principally of concern in more than one media and represent current environmental problems. From the list of Intermedia Priority Pollutants, the following regulations or proposed regulations were selected:

- Lead
  - Clean Air Act, Lead-in-Fuel Regulations
- Asbestos
  - Clean Air Act, National Emission Standard for Hazardous Air Pollutants
  - Clean Water Act, Effluent Limitation Guidelines for Asbestos Manufacturing Point Sources

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<sup>1</sup>ICF Incorporated, Measuring and Comparing the Cost-Effectiveness of EPA Regulatory Efforts to Control Toxics-Related Health Risks--Volume I, Feasibility Study, March 1981.



- Benzene

- Clean Air Act, National Emission Standards for Hazardous Air Pollutants; Maleic Anhydride Plants, Ethylbenzene/Styrene Plants; and Benzene Storage Vessels.

The term "cost-effectiveness analysis," strictly speaking, refers to the methods used in comparing policy alternatives in which either a clearly defined objective has been specified and the alternative programs under study differ only in cost or, more rarely, in situations where the costs of programs are similar, but the alternatives differ in the extent of benefits they produce.<sup>2</sup> Because neither of these conditions holds true for the toxics-related control options analyzed by OTI, a broader, more useful interpretation of cost-effectiveness analysis can be taken as a comparison of quantitative estimates of the positive and negative outcomes of a policy choice, measured in their natural units. This rigorous and systematic examination of expected outcomes in their natural units is a useful and necessary part of an integrated toxics control strategy.

In the feasibility study, we attempted to use health outcomes, e.g., cases of cancer, as the measure of effectiveness. Because of data unavailability and other limitations, these measures are not always easily obtainable. For this reason, EPA asked that, in the current study, we also determine an "effectiveness" measure based on the amount of the pollutant prevented from entering the environment. An important part of this study then involves determining the limitations of tons of emissions prevented as an effectiveness measure. Chapters 2, 3, and 4 present the cost-effectiveness analyses of the regulations studied. Chapter 5 presents our summary and conclusions regarding the limitations of the usefulness of "tons of emissions prevented" as an effectiveness measure.

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<sup>2</sup>E. Stokey, and R. Zeckhauser, A Primer for Policy Analysis, (New York, New York: Norton, 1978), pp. 153-154.

## 2. COSTS AND EFFECTIVENESS OF EPA REGULATIONS LIMITING THE USE OF LEAD ADDITIVES IN GASOLINE

### 2.1 INTRODUCTION

The noxious properties of high-level lead exposures had been recognized by the ancients and were extensively described in the medical literature of the late 19th century. By the mid-1960's, lead poisoning among urban children had been recognized as an important public health problem.<sup>1,2</sup> In addition, it was known that man-made lead emissions had increased the levels of lead found in the environment several orders of magnitude over those in prehistoric times<sup>3</sup> and that the major source of these lead emissions was the combustion of gasoline containing lead-based anti-knock additives.<sup>4</sup> For these reasons, among others, the Environmental Protection Agency promulgated regulations in the early 1970's which dealt with the amounts of leaded and unleaded gasoline that could be produced in the United States, and limited the lead content in automotive fuel. It should be noted that the Presidential Task Force on Regulatory Relief has requested EPA to review the regulations. This may lead to further rulemaking.

The first regulation, promulgated on January 10, 1973<sup>5</sup> contains provisions which require refiners to produce a sufficient amount of unleaded gasoline to supply the needs of the increasing numbers of automobiles whose pollution control equipment would be damaged by the use of leaded fuel. While this regulation did not directly require any decrease in the amount of leaded fuel manufactured, or the lead content of leaded fuel, it did affect the amount of leaded gasoline indirectly by requiring refiners to convert existing refinery capacity to produce unleaded gasoline and expand capacity to meet the anticipated increase in demand for this fuel. It should be noted that this

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<sup>1</sup>J. Chisholm, Jr., and H. Harrison, "The Exposure of Children to Lead", Pediatrics 18, 943-957, 1956.

<sup>2</sup>H. D. Smith, "Pediatric Lead Poisoning", Archives of Environmental Health, 8, 256-61, 1964.

<sup>3</sup>C. C. Patterson, "Contaminated and Natural Environments of Man," Archives of Environmental Health, 11, 344-360, 1963.

<sup>4</sup>Subcommittee on Environmental Improvement, Committee on Chemistry and Public Affairs, American Chemical Society, Cleaning Our Environment, The Chemical Basis for Action (Washington, D.C., 1969).

<sup>5</sup> 38 Federal Register 1255-1258, January 10, 1973.

regulation alone would have produced a large part of the total reduction in lead additive usage required by the lead content phasedown, since all cars produced after 1974 were required to meet emission standards for pollutants other than lead. At that time, the only technology available to meet these standards for most cars were lead-intolerant catalyst systems.

The regulations which directly limited the lead content of gasoline were first promulgated on December 6, 1973.<sup>6</sup> As originally formulated, the rules required that, for each refinery producing automobile fuels, the average lead content of all the gasoline produced in any calendar quarter could not exceed gradually decreasing amounts, as specified by the following schedule:

|                       |                       |
|-----------------------|-----------------------|
| After January 1, 1975 | 1.7 grams lead/gallon |
| After January 1, 1976 | 1.4 grams lead/gallon |
| After January 1, 1977 | 1.0 grams lead/gallon |
| After January 1, 1978 | 0.8 grams lead/gallon |
| After January 1, 1979 | 0.5 grams lead/gallon |

Unlike the unleaded gasoline standard, whose stated purpose was to provide sufficient fuel for catalyst-equipped cars, the rationale for the lead-in-fuel limitation was explicitly based on public health considerations. The preamble of the standard cites Section 211(c)(1) of the Clean Air Act, which allows EPA to prohibit the manufacture or control the use of any fuel additive "if any emission product of such fuel additive will endanger the public health or welfare." Specifically, the preamble states that the standard is based on the finding "that lead particle emissions from motor vehicles present a significant risk of harm to the health of urban populations, particularly to the health of city children."<sup>7</sup> As we discuss below, EPA was not able to demonstrate conclusively that lead emissions due to leaded fuel use harmed the health of children. They did, however, demonstrate that there were correlations between blood lead and air lead levels and the toxic effects produced by lead, and that lead from automobile exhausts did appear to contribute to the amount of lead present in urban air and settled dust, and hence to the total lead exposure received by city children.

EPA stated that its long-term goal was to reduce the level of lead additive usage (and also, hopefully, the emission of lead from automobile exhausts) by 60-65 percent compared to the amount used in 1971.

The regulation was immediately challenged in court, and was set aside by the U.S. Court of Appeals for the District of Columbia in late 1974. In February 1975, EPA suspended enforcement of the standard, and petitioned the court to rehear the case en banc. The court agreed, reheard the case, and upheld the regulation in a decision that set many important precedents for future EPA rulemaking on March 19, 1976.<sup>8</sup> After the Supreme Court refused

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<sup>6</sup> 38 Federal Register 33734-33741, December 6, 1973.

<sup>7</sup> Ibid., p. 33734.

<sup>8</sup> Ethyl Corporation vs. Environmental Protection Agency, 541 F.2d 1 (1976).

to hear the case, EPA resumed enforcement of the standard, but altered the timetable for reductions in the lead content of refinery output.<sup>9</sup> The reason for revising the standard was that many firms had postponed installing new refinery capacity for unleaded fuel pending the outcome of the litigation, and EPA believed that shortages of unleaded fuel might occur. The deadline for achieving the 0.8 gram lead/gallon average fuel composition was kept at January 2, 1978, but refiners who could demonstrate that they had made good-faith efforts to comply would not be penalized for exceeding the limit, if they could also achieve compliance with the 0.5 gram/gallon deadline, which was moved back 8 months to October 1, 1979. In June of 1978, EPA announced that they were suspending all enforcement of the 0.8 gram/gallon limit and proposed to further alter the timetable for attainment of the 0.5 gram/gallon goal.<sup>10</sup> In September of 1978, regulations were promulgated which gave refiners the option of either meeting the 0.5 gram/gallon standard on October 1, 1979, or being allowed to produce at the 0.8 gram/gallon level for an additional year, until October 1, 1980, on the condition that the total amount of unleaded gasoline produced at any refinery would be increased 6 percent over the amount produced a year earlier, or that each refiner produce at least 45 percent unleaded gasoline, whichever was least. Large refineries have been meeting the 0.5 gram/gallon standard since October 1, 1980.

The rationale given for the last two changes in scheduling was that fluctuations in oil supplies (brought about mainly by political instability in the middle east) coupled with the refiners' continued inability to install new refinery capacity could have resulted in shortages of unleaded gasoline. EPA feared that such shortages could cause consumers to use leaded gasoline in catalyst-equipped cars. Such fuel switching, even if it occurred only briefly, had the potential for inactivating the pollution control devices in large number of cars, thus seriously setting back EPA's effort to control other mobile-source pollutants.

Originally, EPA felt that the lead-in-fuel regulations would be the only set of regulations dealing with air pollution by lead and its compounds, since it was known that fuel combustion accounted for almost 90 percent of all man-made lead emissions. In the preamble to the original regulation, EPA denied the request of several environmental groups that they set a National Ambient Air Quality Standard for Lead, in order to control lead air pollution from stationary sources. In 1975, a suit brought by the National Resources Defense Council forced EPA to list lead as an air pollutant for which air quality criteria would be established, and for which a regulation would eventually be developed. The final National Ambient Air Quality Standard for Lead, which required that lead levels in the ambient atmosphere be limited to 1.5 micrograms per cubic meter, was promulgated on December 14, 1977.<sup>11</sup>

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<sup>9</sup> 41 Federal Register, 42675-42677, September 28, 1976.

<sup>10</sup> 44 Federal Register 33116-33118, June 8, 1979.

<sup>11</sup> 42 Federal Register 63076-63083, December 14, 1977.



That regulation has previously been analyzed in other work performed under this contract.<sup>12</sup>

## 2.2 THE COSTS OF THE LEAD-IN-FUEL REGULATIONS

The EPA regulations limiting the use of lead additives in gasoline, especially the regulation requiring the phasing down of the lead content according to a set (but continually revised) schedule, are among the most extensively analyzed regulations in the agency's history. Since the refining industry was aware of the adverse effects of lead exposure due to automobile emissions as early as the mid-1960s, there were sporadic attempts to analyze the likely economic effects of reducing the lead content in fuel well before the lead regulations were being seriously considered by EPA, and in fact before EPA even existed. In addition, the actual rulemaking was accompanied by a flurry of analyses sponsored by both industry and EPA. The extensive litigation surrounding the standard brought about another round of analyses, as did each of EPA's decisions as to whether to extend the deadline in 1976, 1978 and 1979.

For these reasons, there are very many studies which attempt to estimate the economic impacts of one or more aspects of the lead-in-fuel regulations at one particular point in time. Owing to the large number of studies, it was not possible for us to be as comprehensive as we would have liked to be in our review of estimates of the costs of these regulations, nor were we able to devote critical attention to more than a few of the most important studies. Still, we believe that in the brief review which follows, we have identified the most significant studies and been able to critique in a reasonable fashion the most important analytical techniques and assumptions used in them.

Before reviewing specific studies of the costs of the lead-in-fuel regulations, it would be useful to review the important features of the refinery industry and processes which give rise to costs in the case where lead additive usage is limited by regulation.

Tetramethyl and Tetraethyl lead were, at the time of the imposition of the lead-in-fuel regulation (and still are) the most effective and inexpensive anti-knock additives available. Anti-knock additives are used to increase the octane rating of gasoline, which allows it to be used efficiently in automobiles with high compression ratios. Such engines tend to be more efficient because they can generally produce more power per unit of engine weight. Hence, although automobiles can be designed to a certain extent to use low octane fuel, there are some applications where high octane fuel is necessary for efficient operation.

In 1970, when lead-in-fuel regulations were first seriously considered, the average compression ratio of automobiles manufactured in the U.S. was

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<sup>12</sup>ICF Incorporated, Measuring and Comparing the Cost-Effectiveness of EPA Regulatory Efforts to Control Toxics-Related Health Risks--Volume I, Feasibility Study, March 1981.



quite high, which produced a demand for "premium" grade high octane fuel. Over the next several years, the compression ratio of new automobiles declined for a number of reasons (including high gasoline prices), though there was still a sizable residual demand for premium fuel.

The problem faced by refiners, therefore, was to meet the demand for high octane fuel, while at the same time complying with regulations which limited the total lead content in the fuel they produced, and which required them to produce ever increasing amounts of unleaded fuel to supply the expected increase in the number of catalyst-equipped automobiles. Even the latter regulation made certain demands on the refining industry, octane-wise, because the unleaded fuel was required by regulation to have a minimum research octane number of 91 which, while not particularly difficult to produce without lead additives, did occasionally displace refining capacity which could have gone to producing high octane fuel.

Refiners thus had to adjust refining capacity both to meet the need for unleaded fuel and to produce more high octane hydrocarbons which would allow them to gradually reduce the total lead content in their output. To a certain extent, the structure of the standard allowed refiners to simply expand capacity for unleaded fuel and gradually reduce output of lead-containing premium grades, without reducing the lead content in premium gasoline. Even so, the necessity to maintain the average octane ratings in the total gasoline pool required extensive changes in refining techniques.

The "costs" of the lead-in-fuel regulation arises from the necessity to upgrade refining capacity to produce adequate amounts of high octane hydrocarbons, and the additional operating costs of this new capacity. The latter costs could be high because the processes used to increase octane rating, such as reforming or alkylation, are often energy intensive, and produce less fuel per unit of oil consumed. Thus, there are not only increased energy requirements, but a penalty in oil consumption as well.

Studies of the economic impacts of the lead-in-fuel standards have thus focused mainly on a few measures of costs, such as the increases in refinery investments, and changes in operating costs, an important component of which is increased energy cost or decreased refinery efficiency, in terms of energy and oil usage. Occasionally, studies have focused on the likelihood of shortages of the various grades of gasoline that might arise as the result of a particular phase-down strategy. A few studies deal with the effect of the standard on industry profits and on the ability of small refiners to comply without being forced into bankruptcy.

There are two major problems encountered in attempting to use any one study to estimate the economic impact of the lead-in-fuel standard, or in comparing cost estimates between studies. The first problem is that the various studies were conducted at different points in time, and analyzed many regulatory scenarios that never came about, or that didn't closely conform to the regulations as they were actually promulgated. The second problem, actually an extension of the first, is that the lead phase-down regulation was revised and postponed so many times that no one study was able to very accurately predict the schedule of investments undertaken by the refinery

industry. This difficulty is exacerbated by the fact that no serious efforts, that we could find, have been made to retrospectively analyze what the impact of the lead-in-fuel standards actually was on the refinery industry and on gasoline prices. We are thus left with only the prospective studies whose results often depend heavily on the particular scenario analyzed and the exact analytic methods used.

#### 2.2.1 Review of Previous Studies of the Economic Impact of the Lead-in-Fuel Regulations.

The earliest studies of the effects of limitations in lead usage in fuel that we could locate were industry-sponsored studies presented at a symposium on lead pollution held by the Public Health Service in 1965. Both of these studies estimated the costs of immediately removing all lead additives from fuel, while maintaining the existing octane levels of the total fuel pool. Little methodological background is given for these studies, so that it is difficult to assess the validity of the results,\* although the failure to specify a reasonable time frame for compliance probably seriously affects the results of these studies. The first report, by representatives of the Ethyl Corporation,<sup>13</sup> used a linear programming model of refinery operations to predict the effects of an immediate decision to abandon lead additive use. It was predicted that such a decision would require an additional 2.86 billion dollars investment in refinery capacity (over an unspecified length of time) and that gasoline prices would be increased 2.6 cents per gallon, presumably forever (both of these estimates are in 1963 dollars). It was also predicted that the production of sufficient unleaded high-octane fuel would require 396 million barrels of oil per year, or about 12 percent of total oil consumption in that year, and that about 100 small refiners, who would be unable to comply at a reasonable cost, would be forced out of business.

The second study, also produced by the refinery industry, used a less sophisticated methodology, based on studies of two different size model refineries, to estimate that approximately 1.5-2 billion dollars of additional investment would be required nationwide to produce the required amount of unleaded gasoline.<sup>14</sup> This would result in a rise in price to the consumer

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\*This is true for many of the studies analyzed. Many assessments of the lead-in-fuel standard used complex and poorly-described linear programming models, the merits of which were very difficult to evaluate.

<sup>13</sup>W.W. Sabin, R.K. Scales, "Evaluation of Use vs. Non-Use of Tetra-Ethyl Lead in Gasoline," paper presented at the Symposium on Environmental Lead Contamination, December 13-16, 1965, sponsored by the U.S. Public Health Service.

<sup>14</sup>M.J. Sterba, "Refining to Produce Gasoline of Reduced Lead Content," paper presented at the Symposium on Environmental Lead Contamination, December 13-16, 1965, sponsored by the U.S. Public Health Service.

of about 1.1 to 1.5 cents per gallon (1965 dollars). It was estimated that approximately a 2 percent increase in the total consumption of oil would also occur. No mention was made of the possible effects on small refineries, although the switchover was predicted to be possible without serious economic dislocations.

In 1967, the refinery industry sponsored another, more detailed study of the costs of removing lead from gasoline.<sup>15</sup> The results of this analysis again were comparable to the previous two studies. The method used also involved analyses of model refineries, but in this case, regional difference between operating, transportation and feedstock costs were taken into account to generate costs for "typical" refineries in four regions of the country. The increased refinery costs were found to be very dependent on refinery size, ranging from roughly 1.8 to 4.7 cents per gallon, for the largest and smallest refineries, respectively. The national average increase in refinery costs was estimated to be 2.15 cents per gallon, and the total investment required for converting to unleaded gasoline production was 4.24 billion dollars (1965 price levels). No estimate was made of the change in the cost of gasoline to consumers, although it might well have been well above 2.15 cents per gallon, since the investment required to produce sufficient unleaded gasoline was equivalent to about 6 cents per gallon distributed over one years' output.

The three studies just discussed all display a number of weaknesses that make it very difficult to use them as estimates of the economic impact of the lead-in-fuel standard. As mentioned previously, they all estimate the cost of an instantaneous shift to 100 percent unleaded fuel as opposed to the gradual phasedown that actually occurred. Second, none of them deal with the dynamics of the changeover to unleaded fuel, and make no effort to analyze how firms' investments would actually change over time. Finally, they fail to take into account consumer behavior, the shift to low-priced, low octane fuels that could be expected to occur over time, and thus probably overestimate costs. Some of the more recent studies attempt to address some of these issues.

The next three studies to be reviewed were all commissioned by EPA in order to inform the standard-setting process. They are considerably more sophisticated than the previous studies, and to a certain extent, directed toward the analysis of specific regulatory scenarios. None of them analyzes precisely the schedule of phasedown levels that actually was contained in the final standard.

The first of these studies was performed in 1971 by Bonner and Moore, the same firm that had previously analyzed the cost of a sudden shift to unleaded fuel for the petroleum industry.<sup>16</sup> EPA had originally asked for analyses of

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<sup>15</sup>Bonner and Moore Associates, Inc., U.S. Motor Gasoline Economics  
Vol. 1: Manufacture of Unleaded Gasoline, 1967.

<sup>16</sup>Bonner and Moore Associates, Inc., An Economic Analysis of Proposed Schedules for Removal of Lead Additives from Gasoline, June 25, 1971, prepared for the U.S. Environmental Protection Agency under contract 68-02-0050.



11 lead-removal scenarios. This number was later reduced to 4 on the basis of preliminary feasibility studies. Of the 4 scenarios analyzed, two assumed that firms would market three grades of gasoline (one "clear", two leaded) and two assumed that firms would stay with the then common two-grade system. The former assumption was probably the most reasonable one, since most gasoline companies had already begun to invest in three-grade marketing schemes. This study was thus the first to take into account this particular strategy on the part of refiners. The timing of the lead removal required by the various scenarios is summarized in Exhibit 2-1. Scenario A corresponds to the slowest lead removal, in that prior to 1974, refiners would be allowed to market three grades of gasoline, all leaded, the lowest octane grade being allowed to have a lead content of 0.5 gm/gal., which would have to be totally removed after 1973. Scenario L, also a three grade scheme, requires removal of lead from all grades of fuel as rapidly as possible (according to the contractor's assessment). Scenarios G and M correspond to the analogous removal schedules but for a two-grade marketing scheme.

The methodology employed again involved the use of econometric models for fuel demand coupled with linear programming models for model refineries. No economies of scale were specifically taken into account in estimating the costs of new investments, rather, such costs were scaled linearly to estimate an industry average cost. Throughout, it was assumed that the lowest grade unleaded fuel would be required to have a research octane number (RON) of 93 (as compared to a RON 91 which was actually required by the standard). It was assumed that the start date for any fuel regulation would be 1971.

The total added costs to refiners predicted for all of the scenarios are somewhat lower than those estimated in previous studies. No scenario predicts an average added refining cost of more than 0.90 cents per gallon in any year between 1971 and 1980 (Exhibit 2-2). The two slow-removal scenarios predicted that increased costs per gallon would not exceed 0.56 cents per gallon in any year.

Sizable additional investments were required by all scenarios except scenario A, and in the case of the rapid removal scenarios, it was predicted that the necessary rate of new capacity investment would exceed the capacity of the refinery construction industry. Moderate increases in crude oil consumption, (compared to previous studies) were also predicted to occur. In no year for any scenario did they exceed 5.9 percent of total consumption). It was also pointed out that the necessity to increase the aromatic content of unleaded fuel could produce instability in the market for aromatic organic chemicals. The fact that small refiners would be at a very great disadvantage in attempting to comply with the regulation was also mentioned.

It can be seen, from Exhibit 2-1, that scenario A, the slow removal, three-grade scheme for lead reductions, conforms rather closely, in terms of total pool lead content reductions, to what actually occurred in 1971-1978. This does not necessarily imply that the industry undertook investments at the rate predicted, or that the octane ratings and lead contents of the various grades of gasoline conformed to the scenario, but it does suggest that scenario A most correctly predicts the major features of the reduction in lead content, and thus could be expected to provide the most accurate estimates of the impacts of the standard on the gasoline industry.

## EXHIBIT 2-1

LEAD REMOVAL SCENARIOS ANALYZED BY  
BONNER AND MOORE (1971), COMPARED TO ACTUAL LEAD REMOVAL

| <u>Scenario</u>        | <u>Total Lead Pool Content, Grams/Gallon</u> |             |             |             |             |             |             |             |             |             |
|------------------------|----------------------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
|                        | <u>1971</u>                                  | <u>1972</u> | <u>1973</u> | <u>1974</u> | <u>1975</u> | <u>1976</u> | <u>1977</u> | <u>1978</u> | <u>1979</u> | <u>1980</u> |
| A                      | 2.0                                          | 2.0         | 1.9         | 1.8         | 1.7         | 1.6         | 1.3         | 1.1         | 1.0         | 0.9         |
| L                      | -                                            | 0.8         | 0.6         | 0.4         | 0.1         | 0.0         | 0           | 0           | 0           | 0           |
| G                      | 1.3                                          | -           | -           | 0.56        | -           | -           | -           | -           | -           | 0.1         |
| M                      | 0.8                                          | -           | -           | 0.40        | -           | 0.01        | -           | -           | -           | 0.0         |
| (Actual) <sup>a/</sup> | 2.17                                         | 2.11        | 2.04        | 1.79        | 1.58        | 1.61        | 1.48        | 1.25        | -           | -           |

a/ SOURCE: SRI International, Chemical Economics Handbook.

## EXHIBIT 2-2

PREDICTED ADDED REFINERY COSTS PER GALLON  
FOR LEAD DEMAND SCENARIOS (BONNER AND MOORE, 1971)

| <u>Scenario</u> | <u>Total Added Costs, cents/gallon</u> |             |             |             |             |             |             |
|-----------------|----------------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|
|                 | <u>1971</u>                            | <u>1972</u> | <u>1973</u> | <u>1974</u> | <u>1975</u> | <u>1976</u> | <u>1980</u> |
| A               | 0.16                                   | 0.20        | 0.23        | 0.22        | 0.22        | 0.21        | 0.21        |
| L               | -                                      | 0.48        | 0.56        | 0.62        | 0.85        | 0.90        | 0.60        |
| G               | 0.19                                   | 0.24        | 0.22        | 0.56        | 0.53        | 0.51        | 0.36        |
| M               | -                                      | 0.20        | 0.24        | 0.31        | 0.51        | 0.68        | 0.43        |



In Exhibit 2-3, it can be seen that the various impacts of scenario A are indeed modest, compared to previous estimates of the impacts of lead reduction. Total investment required for the entire period 1971-1980 is 1.46 billion dollars, and in no year does investment exceed 187 million dollars (compared to total capital investment in new capacity in the industry of about 1 billion dollars in 1970). No adverse cyclical effects were predicted to occur in the construction industry under this scenario.

## EXHIBIT 2-3

ECONOMIC IMPACTS OF "SCENARIO A" (BANNER AND MOORE, 1971)

|                                          | <u>1971</u> | <u>1972</u> | <u>1973</u> | <u>1974</u> | <u>1975</u> | <u>1976</u> | <u>1980</u>         |
|------------------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|---------------------|
| Investment (million \$/year)             | 15          | -           | 42          | 187         | 122         | 172         | 1,462 <sup>a/</sup> |
| Total Added Cost<br>(¢/gallon)           | 0.16        | 0.20        | 0.23        | 0.22        | 0.22        | 0.21        | 0.21                |
| Increase in Crude Oil<br>Consumption (%) | 0.34        | 0.67        | 1.37        | 3.90        | 1.65        | 2.42        | 3.16                |

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<sup>a/</sup> Total cumulative investment 1971-1980.

The present value of all of the added investments between 1971 and 1980 (in 1971 dollars, 10 percent discount rate) was 0.85 billion dollars. To this cost must be added the additional cost of going from a two-grade to a three-grade marketing scheme. This cost was calculated to be 1.29 billion dollars, of which firms had already invested \$746 million by the beginning of 1971. If it is assumed that all of the investment in the three-grade system should be attributed to the regulation, then the total present value of this investment is 1.2 billion in 1971 dollars.<sup>17</sup> This makes the total monetary cost of converting to unleaded fuels 2.1 billion dollars, calculated at 1971 price levels. If it is assumed that firms might have gone to a three-grade system independent of the lead-in-fuel regulation, these costs would be reduced accordingly.

In 1972, EPA commissioned Stephen Sobotka and Company to study in more detail the impacts of the lead-in-fuel standards on the viability of refiners and distributors.<sup>18</sup> The two major focuses of this study were the costs of

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<sup>17</sup>Assuming all of the previously-spent \$746 million was invested in 1971, and that the additional \$548 million would be invested 50 percent in 1972 and 50 percent in 1973 (10 percent discount rate).

<sup>18</sup>Stephen Sobotka and Company, "Economic Impact of Lead Content in Gasoline Regulations on the Refining and Marketing Segments of the Petroleum Industry," prepared for the Environmental Protection Agency, June 30, 1972.

installing three-grade distribution systems and the impacts of the increased "clear" octane requirements on individual refineries.

Sobotka calls into question Bonner and Moore's estimate of the cost of installing three-grade dispensing systems at service stations, suggesting that this cost might be as low as \$2,500 per station, compared to the \$8,000 per station used by Bonner and Moore in their estimates of total national costs. The investigators considered it unlikely that the cost of installing a third grade would result in the closure of more than a few service stations, pointing out that in the long run, a three grade station would be much more profitable than a two grade station, and that the payback period of any investment in three grade distribution would be quite short.

Sobotka next analyzed the U.S. refinery industry, breaking it down into segments, depending upon the techniques available to them to obtain compliance with the lead-in-fuel standard. As in previous analyses, it was pointed out that large refineries (capacity greater than 30,000 barrels per day) were unlikely to have any trouble meeting the standard.

It was also pointed out that the large majority of the small refiners could either still sell their products economically after installing new capacity, or were in a position to remain in operation without installing new capacity because they were in close enough proximity to other refiners to profitably trade low octane products for high octane stock. A few isolated small refineries (about 10, comprising 0.75 percent of the total U.S. refining capacity) were expected to close, due to their inability to comply with the standard. No analysis of changes in profitability of the large refineries, or of the various classes of small refineries, was undertaken.

The final study that, as far as we can tell, was used by EPA to inform the initial rulemaking proceedings, was an elaboration of the previous study by Bonner and Moore, which analyzed in more detail the two three-grade lead reduction scenarios.<sup>19</sup> The analytical methods used were the same as those employed in their previous study, but several key assumptions were changed and the focus of the analysis was expanded somewhat to include estimates of actual increases in cost that would be experienced by gasoline consumers and, an analysis of the effects of the developments of new, more fuel-efficient, low emission engines.

The major change in analytical assumptions had to do with the attribution of fuel economy changes to the lead standard. The previous study had included reductions in fuel efficiency due to the necessity of complying with emission standards for other pollutants as an impact of the lead standard. The new analysis included these efficiency changes in the base case, so they were not attributed to the lead standard.

Exhibit 2-4 summarizes the projected effects of two lead reduction scenarios on the investment required of the refinery industry to produce the

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<sup>19</sup>Bonner and Moore, Associates, Inc., "Economic Impact of Lead Removal from Motor Gasolines," prepared for the Environmental Protection Agency, July 27, 1973.

necessary amounts of unleaded gasoline at the specified octane levels. In this exhibit, "Step 1" corresponds roughly to the costs associated with scenario A in the 1971 study, that is, the slow phasing out of leaded fuel without specific limitations on the lead content of any grade before 1974. The second row in Exhibit 2-4, "Step 2," corresponds to scenario L, which involves a rapid reduction in the lead content of all grades of gasoline. Because the numbers in Exhibit 2-4 represent the change in total cumulative investment rather than the change in yearly investments, it is difficult to convert them accurately into dollar values without knowing what the projected base rate of investment was predicted to be. If, for the purpose of simplification, one were to assume that refinery investments continued to increase at the pre-1971 rate of about 12 percent per year,<sup>20</sup> the total increase in cumulative investment for the period 1970-1980 would be approximately 2.36 billion dollars for "step 1" and about 2.44 billion dollars "for Step 2." These estimates are both above the 1971 estimates for the cost of scenario A and below the estimates for scenario L (which were 1.46 and 3.46 billion dollars, respectively).

## EXHIBIT 2-4

INCREASE IN REFINERY INVESTMENT BROUGHT ABOUT  
BY LEAD-IN-FUEL REGULATIONS (BONNER AND MOORE, 1973)

|        | <u>Percent Increase in Cumulative Investment</u> |             |             |             |             |
|--------|--------------------------------------------------|-------------|-------------|-------------|-------------|
|        | <u>1973</u>                                      | <u>1975</u> | <u>1977</u> | <u>1980</u> | <u>1985</u> |
| Step 1 | 6.2                                              | 4.5         | 13.4        | 12.0        | 10.4        |
| Step 2 | 6.2                                              | 6.3         | 16.3        | 15.6        | 12.3        |

This study was the first which attempted to estimate the actual cost to consumers of the lead-in-fuel regulations. Again, this was done on a proportional basis. The results are summarized in Exhibit 2-5. It can be seen that the projected increases in the total U.S. gasoline bill are on the order of 1 to 3.5 percent for both scenarios studied for the years 1973-1985. Projected increases in fuel costs were also modest, either in terms of the total national gasoline bill, or in terms of the average cost of gasoline per mile (Exhibit 2-5). It should be noted that these cost estimates assume a constant absolute profit level will be realized by the refinery industry, which may not be a realistic assumption. Using actual average gasoline price levels,<sup>20</sup> these proportional increases in gasoline costs translate into price changes of 0.64, 0.69, and 1.61 cents per gallon in 1973, 1975, and 1977, respectively, with the corresponding increase into total gasoline costs of 64.5, 69.4, and 173.9 million dollars for these three years, respectively.

<sup>20</sup>Bonner and Moore, 1971 op. cit..

## EXHIBIT 2-5

CHANGES IN FUEL COSTS BROUGHT ABOUT  
BY THE LEAD-IN-FUEL REGULATIONS (BONNER AND MOORE, 1973)

Changes in Total National Gasoline Costs (%)

|        | <u>1973</u> | <u>1975</u> | <u>1977</u> | <u>1980</u> | <u>1985</u> |
|--------|-------------|-------------|-------------|-------------|-------------|
| Step 1 | 1.19        | 1.18        | 2.29        | 2.97        | 3.35        |
| Step 2 | 1.19        | 1.18        | 2.48        | 3.20        | 3.40        |

Changes in Average Gasoline Costs Per Mile (%)

|        | <u>1973</u> | <u>1975</u> | <u>1977</u> | <u>1980</u> | <u>1985</u> |
|--------|-------------|-------------|-------------|-------------|-------------|
| Step 1 | 0           | 0.63        | 1.09        | 1.75        | 2.14        |
| Step 2 | 0           | 0.63        | 1.12        | 1.97        | 2.21        |

As in the previous studies, it was predicted that increased raw material usage would occur. For "step 1," the increase in raw material usage was predicted to gradually rise from 0.7 percent in 1973 to 2.7 percent in 1985. For step 2, the increases in raw material usage was projected to behave similarly, and rise from 0.7 percent in 1973 to 2.9 percent in 1985. These numbers cannot be directly compared to the changes in oil consumption calculated in previous studies because they include adjustments related to the amount of fuel used to provide electricity, steam, and process heat to the refinery, and to the amount of byproduct fuel gas generated in the course of gasoline production.

After the promulgation of the lead-in-fuel regulations, a number of other important studies were performed which attempted to estimate the costs of the standards and its economic impact on the refinery industry, consumer and the economy. The first of these was a study by A.D. Little, Incorporated (ADL),<sup>21</sup> which projected energy, cost and oil consumption impacts of the lead-in-fuel regulations that were actually in effect at the time.<sup>22</sup> Thus, this study was the first to analyze the impacts of lead regulations, rather than some postulated schedule of lead reduction. This does not necessarily mean that this is a more accurate study; the lead phasedown schedule was revised three times after this study was published. It is also not clear that the models used to predict costs were any more accurate than anyone else's.

<sup>21</sup>Arthur D. Little, Incorporated, Impact of Motor Gasoline Lead Additive Regulations on Petroleum Refineries and Energy Resources 1974-1980, Phase I, prepared for the Environmental Protection Agency, May 1974.

<sup>22</sup>These included both the unleaded fuel regulations and the original 1975-1979 schedule of lead content reductions.



This study used the now-standard linear programming-model refinery approach to estimate the impacts of the lead regulations. Several key analytic assumptions had changed from previous studies, however, including:

- Rapid increases in oil prices resulting from rapidly increasing demand and the action of oil producing countries, which would strongly affect the nature of least-cost refinery strategies were taken into account.
- Changes in fuel demand forecasts were included which accurately reflected increases in the fuel-efficiency of catalyst equipped cars. These reductions in demand gave refiners more leeway in choosing least-cost strategies.

The latter assumption, in particular, strongly affected the magnitude of the economic impacts as predicted by this study. The predictions of this study differ in several important ways from those generated by other studies both in terms of the magnitude and timing of costs (Exhibit 2-6). Owing primarily to the improvements in fuel economy described earlier, few impacts of the standards are predicted to occur prior to 1977. Between 1977 and 1980, relatively modest impacts on crude oil and energy consumption were predicted to occur. During this period, it was predicted that firms would engage in moderately intense construction programs to build new refinery capacity. The total cost per gallon of gasoline, however, is predicted to be very small (0.01 cents per gallon in the years 1974-76 and 0.04 cents per gallon in 1977-1980).

It should be noted that these figures refer to the effects of both the unleaded fuel manufacturing requirement and the lead content phasedown. It is not very meaningful, as was discussed earlier, to measure the effect of each regulation separately, since many aspects of refiner behavior can be attributed to either standard.

## EXHIBIT 2-6

PREDICTED ECONOMIC IMPACTS OF THE LEAD-IN-FUEL REGULATIONS  
(A.D. Little, 1974)

|                                                                                                     | <u>1974-76</u> | <u>1977-1980</u>               |
|-----------------------------------------------------------------------------------------------------|----------------|--------------------------------|
| Additional Investment<br>(Million dollars per year)                                                 | 0              | 370                            |
| Change in Gasoline Cost<br>(c/gallon)                                                               | 0.01           | 0.04                           |
| Increase in Crude Oil<br>Consumption (Million barrels<br>per year, percent of total)                | 0              | 21.2-26.3<br>(0.3-0.4 percent) |
| Total Change in Energy Inputs<br>(million barrels oil-<br>equivalent per year, percent<br>of total) | 0.73           | 7.3-19.9<br>(0.2-0.3 percent)  |

This study also engaged in detailed analyses of the methods that could be used by refineries with specific characteristics to comply with the lead standards. It was concluded that most major refineries would have no trouble complying with the standard. The problems faced by small refiners were not addressed.

The next study commissioned by EPA was more a review of previous research than an original study. The study, by Turner, Mason and Solomon, dealt with the effects of all of EPA's regulations on the refining industry, not just the lead standard.<sup>23</sup> The only results germane to this analysis were updated estimates of investments and operating costs for the lead-in-fuel standards from previous studies by the same firm. It was estimated that the switchover to lead-free fuel (no specific scenario or regulatory scheme was mentioned) would cost the industry a total of 3.2 billion dollars in added investments between 1971 and 1985, about 2.0 billion dollars by 1980. It was also estimated that increased operating costs due to lead removal would rise from 330 million dollars per year in 1977 to 690 million dollars per year in 1985 (all estimates are 1974 dollars). No analysis of the impacts on fuel prices, energy or crude oil consumption, or the affects on fuel prices were performed.

In 1976, Arthur D. Little, Incorporated completed a study for EPA which used refined modelling techniques to update and revise the results of their

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<sup>23</sup>Turner, Mason and Solomon, Consulting Engineers, An Analysis of the Impacts of EPA's Regulations on the Petroleum Refining Industry, EPA contract No. 68-01-2830, June 24, 1975.

previous work on the economic impacts of lead-in-fuel regulations.<sup>24</sup> In this work, ADL used 8 linear programming models to simulate presently existing refineries and refineries which would have to be built to supply the demand for unleaded gasoline between now and 1985. The models for existing capacity were based on the operating characteristics of actual refineries, and took into account the geographical distribution of refineries that would allow refinery operators to optimize output across clusters of refineries by trading fuel stocks as needed. Conventional fuel demand models were used to predict future requirements for unleaded fuel production.

The major results of the study are summarized in Exhibit 2-7. These results are quite different from the predictions generated earlier by the same firm, using similar techniques. The capital investment required through 1980 increased about 60 percent in real terms from previous estimates, as did the projected increase in crude oil consumption and the net energy penalty associated with unleaded fuel production increased about 30 percent for the period 1977-1980. The total refining costs per gallon for 1977 and 1980 are more than 10 times higher than predicted in 1974. All these increases are predicted despite the fact that the "cluster" assumption would be expected to reduce total costs.

## EXHIBIT 2-7

PREDICTED ECONOMIC IMPACTS OF LEAD-IN-FUEL REGULATIONS  
(A.D. Little, 1976)

|                                                                           | <u>1977</u> | <u>1980</u> | <u>1985</u> |
|---------------------------------------------------------------------------|-------------|-------------|-------------|
| Cumulative Capital Investment<br>(million dollars)                        | 1,600       | 3,500       | 5,700       |
| Refinery Costs<br>(¢/gallon) <u>a/</u>                                    | 0.25        | 0.56        | 1.71        |
| Increase in Crude Oil<br>Consumption (thousand<br>barrels/day)            | 93.6        | 114.7       | 255.5       |
| Net Change in Energy Input<br>(thousand barrels of oil<br>equivalent/day) | 52.0        | 55.0        | 180.0       |

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a/ Calculated for total gasoline pool, assuming 32 percent unleaded gasoline use in 1977, 60 percent in 1980, and 100 percent by 1985.

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<sup>24</sup>Arthur D. Little, Incorporated, The Impact of Lead Additive Regulations on the Petroleum Refining Industry, prepared for the Environmental Protection Agency, May 1976.

All in all, the 1976 ADL study predicts the total cumulative investment required to comply with the 1973 lead-in-fuel regulation would be 5.7 billion dollars (1975 prices). Of this total, approximately 44 percent would go to upgrading existing refinery capacity, and the remainder would be used to construct new capacity. The study specifically failed to address the issues of the costs of a three-fuel distribution system, the ability of the construction industry to build refinery capacity at a sufficient rate to meet the demand for unleaded fuel, and the effect the lead-in-fuel regulations would have on small refiners.

The final major study of the costs of the 1973 lead-in-fuel standards was commissioned by the American Petroleum Institute and completed in June of 1976 by Battelle Columbus Laboratories.<sup>25</sup> This study, which analyzed the effects of all major regulations on the refinery industry (not just lead), used previously published studies of the projected effects of regulations to generate independent estimates of their impacts. In the case of the lead-in-fuel standards, Battelle made extensive use of the studies by Bonner and Moore; Turner, Mason and Solomon, and the 1974 ADL report (all previously reviewed here) to develop estimates of the average cost of producing unleaded fuel, the additional investment required to do so and the changes in energy consumption that would be involved. They used these estimates, along with their own projections for gasoline demand to produce detailed estimates of the cost of the lead-in-fuel regulations. Their results are summarized in Exhibit 2-8. It is perhaps not surprising that the results they obtained are on the same order of magnitude of the previously mentioned studies. They predict that a total of 1.9 billion dollars in investment would be required by 1985, that refinery costs would be increased between 0.47 and 0.87 cents per gallon between 1977 and 1985, and that energy consumption would be increased by the lead-in-fuel regulations between 54 and 128 thousand barrels of fuel-oil equivalent per day over that period.

The Battelle report was apparently the last systematic attempt to estimate the economic impact of the lead-in-fuel standard taken as a whole. In 1976, EPA commissioned Sobotka to study the impacts of enforcing the phasedown schedule that would have required refineries to achieve a 1.0 gm/gal total pool lead content by January 1, 1977.<sup>26</sup> This report studies the impacts of the renewed enforcement on refiners, and concluded that they could not possibly meet the 1.0 gm/gallon deadline because there was not sufficient high octane refining capacity available to meet the demand for unleaded gasoline. No quantitative estimates of the costs of compliance were developed in this or in any of a number of other studies that EPA later commissioned to analyze the effects of various changes in the lead phasedown schedule.

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<sup>25</sup>Battelle Columbus Laboratories, The Economic Impact of Environmental Regulations on the Petroleum Industry -- Phase II Study, June 1976.

<sup>26</sup>Sobotka and Company, Incorporated, "Economic Impact on Petroleum Refineries of Lead Additive Phasedown," Environmental Protection Agency contract #68-01-4174, October 29, 1976.



## EXHIBIT 2-8

PROJECTED ECONOMIC IMPACTS OF THE LEAD-IN-FUEL REGULATION  
(Battelle, 1976)

|                                                                                              | <u>1977</u> | <u>1980</u> | <u>1985</u> |
|----------------------------------------------------------------------------------------------|-------------|-------------|-------------|
| Cumulative Increase in Refinery Investment (million dollars)                                 | 1,005       | 1,815       | 1,892       |
| Increased Refinery Costs (¢/gallon) <u>a/</u>                                                | .47         | .83         | .87         |
| Increased Energy Consumption (thousands of barrels of fuel oil equivalent per day) <u>b/</u> | 54.4        | 111.5       | 127.6       |

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a/ Total annualized costs (1974 dollars) divided by total gasoline demand (leaded and unleaded).

b/ Assumes 6.287 million Btu per barrel fuel oil equivalent.

#### 2.2.2 Comparison of Estimates of the Economic Impacts of the Lead-in-Fuel Regulations

Exhibit 2-9 summarizes the estimates of the magnitude of the various economic impacts of the lead-in-fuel regulation, as contained in the studies that were reviewed in the previous section. It can be seen that most of the major studies can be compared on the basis of estimates of one or more of the several impacts, namely, the effect of the standard on investment in the refinery industry, increases in refining costs, increased energy consumption and increased crude oil consumption brought about by the regulations.

Not all of the studies develop estimates of all of these impacts, however, and only the relatively recent studies actually attempted to analyze the impact of the regulatory scheme that was actually promulgated in 1973. None of the studies addresses the issue of how further revisions of the lead phasedown schedule (which has occurred twice since 1973) would affect the impacts of the standard, although, the 1971 Bonner and Moore study included one scenario that conforms quite well to the rate of reduction in the amount of lead in gasoline that actually occurred between 1970 and 1978. Only the monetary impacts of the scenarios are included in Exhibit 2-9. The non-monetary impacts of the standard (changes in crude oil and energy consumption, and the predicted regional and sectoral effects) should be directly comparable in the units in which they are presented, as long as the

## EXHIBIT 2-9

## SUMMARY OF ESTIMATES OF THE ECONOMIC IMPACTS OF THE LEAD-IN-FUEL REGULATIONS

| Study                             | Scenario                                                                       | Cumulative<br>Refinery<br>Investment<br>(Billion Dollars)<br>1971-80 | 1971-85 | Increased<br>Refining<br>Costs (Cents/<br>Gallon, Total<br>Gasoline Pool) | Increased Crude<br>Oil Consumption<br>(Thousand Barrels/Day) | Increased<br>Energy<br>Consumption<br>(Thousand Barrels<br>Oil-Equiv./Day) | Other<br>Impacts                                                                                                     |
|-----------------------------------|--------------------------------------------------------------------------------|----------------------------------------------------------------------|---------|---------------------------------------------------------------------------|--------------------------------------------------------------|----------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|
| Sabin & Scales<br>(1965)          | Immediate Lead Removal                                                         | 3.01/                                                                | --      | 2.6 (permanent)                                                           | 1,000 (permanently)                                          | NA                                                                         | --                                                                                                                   |
| Sterba (1965)                     | Immediate Lead Removal                                                         | 1.5-2.01/                                                            | --      | 1-1.5 (permanent)                                                         | --                                                           | --                                                                         | --                                                                                                                   |
| Bonner & Moore (1967)             | Immediate Lead Removal                                                         | 4.242/                                                               | --      | 2.15 (permanent)                                                          | --                                                           | --                                                                         | Regional cost<br>impacts                                                                                             |
| Bonner & Moore (1971)             | Many schedules, scenario "A"<br>best captures actual course<br>of lead removal | 1.4623/                                                              | --      | 0.16 (1971)<br>0.21 (1976-80)                                             | 41.6 (1971)<br>358.9 (1976)<br>567.1 (1980)                  | --                                                                         | Distribution<br>costs for 3-<br>grade mar-<br>keting, 1.24<br>billion dollars                                        |
| Bonner & Moore (1973)             | Rapid lead removal, complete<br>in several years                               | 2.445/                                                               | --      | -0.02 (1973)<br>0.014 (1985)                                              | --                                                           | --                                                                         | Calculated<br>changes in<br>gasoline<br>prices, total<br>raw materials<br>use, noted<br>effects on<br>small refiners |
| ADL (1974)                        | 1973 regulations (unleaded<br>fuel requirement plus<br>phasedown               | 1.485/                                                               | --      | 0.01 (1974-76)<br>0.04 (1977-80)                                          | 0 (1974-76)<br>58-72 (1977-80)                               | 4 (1974-1976)<br>30-50 (1977-80)                                           |                                                                                                                      |
| Turner, Mason & Solomon<br>(1975) | Rapid lead removal                                                             | 2.06/                                                                | 3.2     | --                                                                        | --                                                           | --                                                                         | Increased<br>operating<br>costs also<br>estimated                                                                    |
| ADL (1976)                        | 1973 regulations                                                               | 3.56/                                                                | 5.7     | 0.25 (1977)<br>0.56 (1980)<br>.71 (1985)                                  | 93.6 (1977)<br>114.7 (1980)<br>255.5 (1985)                  | 52 (1977)<br>55 (1980)<br>180 (1985)                                       | --                                                                                                                   |
| Battelle (1976)                   | 1973 regulations                                                               | 1.825/                                                               | 1.89    | .47 (1978)<br>.83 (1980)<br>.87 (1985)                                    | --                                                           | 54.0 (1977)<br>111.5 (1980)<br>127.6 (1985)                                | --                                                                                                                   |

1/All estimates for this study are in 1963 dollars.

2/Estimates in 1965 dollars.

3/1971 dollars.

4/1973 dollars.

5/1974 dollars.

6/1975 dollars.

issue of intertemporal comparability is kept in mind, that is, barrels of oil or oil equivalent are not worth the same amount in different years.

The monetary impacts of the standards are not directly comparable as presented in Exhibit 2-9 for several reasons. First, each study postulates a different time distribution of investment, so that in order to compare investments, one must disaggregate and discount to some base year. The relative magnitude of the costs of investment predicted by the various studies depend to a very great extent on the base year chosen for discounting. This is because different studies predict very different time patterns of investment.

To facilitate comparison of the magnitude of investments predicted to occur by the different studies, we have chosen 1971 as a base year, and discounted all cost estimates (at 10 percent) to a present value at the beginning of that year. In doing so, we have taken into account the fact that the original estimates of investment were made in dollars from different years; the present values have been inflated to 1980 price levels using the standard GNP price deflator.

The resulting 1971 net present values of the investment streams predicted by the various studies of the lead-in-fuel regulations are summarized in Exhibit 2-10. The exhibit contains values for only those studies which: (1) analyze a lead-removal scenario which reasonably approximates that which actually occurred, and (2) provide at least some detail as to how investments were distributed in time, rather than just giving cumulative investment estimates. The exact magnitude of the present value of the investment streams of course depends on the year which is chosen as the base for discounting and the extent of inflation that has occurred between the base year and the year in which the dollar levels of costs are presented. The relative values of these investment streams, however, should be reasonably independent of the base year chosen and the extent of inflation, as long as all of the investment stream is included in the calculation. The relative value of the investment streams also depends on the interest rate chosen for discounting because the timing of the investment streams differs substantially from study to study.

Also included in Exhibit 2-10 are the 1971 present values (inflated to 1980 dollars) of any other monetary costs which are predicted to be associated with the lead-in-fuel standard. Only two of the studies (Turner, Mason and Solomon, and Battelle) explicitly calculate increased operating costs associated with the lead reductions. The remainder of the studies either do not address the issue or generate estimates of total costs per gallon of fuel that may or may not include contributions from the cost of capital for new refinery capacity, increased energy and crude oil usage or other expenses. In addition, the cost per gallon may be spread over the projected values of either all gasoline production or all unleaded fuel production, and thus are highly dependent on the specific demand predictions and fuel grade mix scenarios in each study. We were thus unable to perform comparisons on all of these costs for the majority of these studies.

EXHIBIT 2-10

COMPARISON OF IMPACT ESTIMATES

| Study                   | 1971<br>Present<br>Value of<br>Investments<br>Through 1980 <sup>a</sup> /<br>1.01 | 1971<br>Present<br>Value of<br>Investments<br>Through 1985 <sup>a</sup> /<br>NE | 1971<br>Present<br>Value of<br>Other Costs <sup>b</sup> /<br>NE <sup>b</sup> /<br>2.16 (three-grade<br>marketing) | Increases in<br>Crude Oil Usage<br>(Thousand Barrels/Day)<br>0 (1974-76)<br>58-72 (1977-80)<br>41.6 (1971)<br>358.9 (1976)<br>567.1 (1980) | Increases<br>in Total<br>Energy Usage<br>(Thousand Barrels<br>Oil-Equiv./Day)<br>4 (1974-76)<br>30-50 (1977-80)<br>NE |
|-------------------------|-----------------------------------------------------------------------------------|---------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|
| ADL (1974)              |                                                                                   |                                                                                 |                                                                                                                   |                                                                                                                                            |                                                                                                                       |
| Bonner & Moore (1971)   | 1.51                                                                              | NE                                                                              |                                                                                                                   |                                                                                                                                            |                                                                                                                       |
| Battelle (1976)         | 1.88                                                                              | 1.90                                                                            | 1.46 operating<br>costs through 1980                                                                              | NE                                                                                                                                         | 54.0 (1977)<br>11.5 (1980)<br>127.6 (1985)                                                                            |
| Turner, Mason & Solomon | 1.95                                                                              | 2.46                                                                            | 2.32 operating costs<br>through 1985                                                                              | NE                                                                                                                                         |                                                                                                                       |
|                         |                                                                                   |                                                                                 | 2.06 operating costs<br>through 1980                                                                              | NE                                                                                                                                         |                                                                                                                       |
|                         |                                                                                   |                                                                                 | 3.28 operating costs<br>through 1985                                                                              |                                                                                                                                            |                                                                                                                       |
| ADL (1976)              | 2.75                                                                              | 3.59                                                                            | NE                                                                                                                | 93.6 (1977)<br>114.7 (1980)<br>255.5 (1985)                                                                                                | 52 (1977)<br>55 (1980)<br>180 (1985)                                                                                  |

<sup>a</sup>/Billions of dollars (first quarter 1980 price levels).

<sup>b</sup>/NE = not estimated.



Exhibit 2-10 also contains estimates of the range of the non-monetary impacts of the lead-in-fuel regulation, taken from the major studies. In principal, it would have been possible to monetize these quantities by applying actual cost factors (for barrels of crude oil, Btu of energy) in the various years in which the impacts occurred. However, it is not clear that this would be a very meaningful exercise, since the predictions of the studies themselves were very dependent on energy and crude oil price levels, and as far as we could tell, none of the studies anticipated the very rapid increase in energy cost that occurred in 1977-1980. This failure to anticipate the rapid rise in energy costs may also have affected the accuracy of the investment predictions.

From Exhibit 2-10, it can be seen that the estimates of the capital investment required to comply with the lead standard cluster rather closely together, considering the uncertainties involved, especially in the case of the three most recent studies. The two studies which estimate increased operating costs differ by about 60 percent. To a certain extent this agreement is not surprising since several of the studies build on results from previous research (especially the Battelle study) and all start from basically the same assumptions.

Estimates of the impact on crude oil usage do not agree as well, with almost a 10-fold difference between the lowest and highest estimates for 1980 consumption. The increased overall energy usage predicted to result from the lead-in-fuel standard agrees more closely between studies, at least in terms of prediction about 1980, where there is only a three fold difference between the highest and lowest values.

In summarizing this information, it is hard to pick a "best" single value; all of the recent studies which analyzed the actual 1973 regulations or something similar, came to rather similar conclusions about the impact of the standard. Further study, in terms of actually validating the complex models used to make these predictions, is beyond the scope of this research.

We see no reason not to take the average values generated by these studies as the best estimates, and using the range of estimates as a measure of reasonable upper and lower bounds. Using this approach, our best estimates of the 1971 present value of the investments required between 1971 and 1980 is 1.82 billion (1980) dollars, while the value of investments required through 1985 is 2.65 billion 1980 dollars. Operating costs through 1980 were about 1.76 billion dollars, and through 1985, they would be about 2.80 billion dollars. The total monetary costs of the lead-in-fuel regulation would then be about 3.6 billion dollars through 1980 and about 5.5 billion (1980) dollars through 1985. Depending upon the extent to which one wished to attribute the costs of the three-grade marketing system to the lead-in-fuel standard, the costs could be increased by as much as an additional 2.16 billion dollars.

Similarly, our best estimates of the increased crude oil consumption due to the lead-in-fuel regulation would be about 250 thousand barrels per day, keeping in mind that there is a large degree of uncertainty associated with this figure. The increase in total energy consumption for 1980 would be about 72 thousand barrels of fuel oil equivalent per day.

### 2.2.3 Possibilities for Improved Cost Estimates

As we stated previously, it was not possible for us to go through each study and examine in detail the working of each of the models (fuel demand forecasts, linear programming refinery models, etc.) used to generate the cost estimates. Thus, it is difficult to suggest any easy ways to improve the accuracy of the impact estimates. Obviously, one way to obtain better estimates of the impacts of the lead in fuel standard would be to conduct a large-scale retrospective analysis, using data about the actual consequences of the standards to generate measures of impact. Considering the difficulty of assembling the data for such a study, and the problems associated with trying to predict what industry behavior would have been in the absence of the standard, it is not surprising that such an analysis has not been undertaken.

Several suggestions do occur to us as to how one could better evaluate the accuracy of the various studies, and possibly generate independent estimates of the impacts of the standard. First, a more detailed analysis of the studies could demonstrate which of them was most accurate at predicting fuel demand, octane mix, and energy and oil prices over time. Clearly, the study that did the best job at making these predictions has a better chance of being accurate than those that did not. It might even be possible, after comparing predictions about fuel and energy demand to make marginal adjustments to the result of the studies and produce revised estimates of costs and other economic impacts.

Another approach that could be taken would be to examine the very basic assumptions that were made at the start of many of these studies, having to do with industry behavior in the absence of the lead regulation. It appears that many of the studies assume a sort of a status quo as a baseline (no regulation) case, and assume that there would have been no decrease in lead usage in the absence of the lead regulation. In view of the fact that many firms had started to reduce the lead content in gasoline well before the standards (even though this may have been in part due to anticipation of the regulation), it may therefore, not be accurate to attribute all the costs of manufacturing and distributing unleaded gasoline to the lead-in-fuel regulations. At the very least, one could analyze the available studies and see which of them made the most reasonable "baseline" assumptions, and evaluate the results of the other impact studies in light of that information.

The fact remains that no retrospective studies of the lead-in-fuel regulations that were originally promulgated, nor the impacts of the subsequent revisions to those standards, has been performed. None of the prospective studies that we reviewed analyzed the effects of the post-1973 delays and revisions in the lead phasedown, although one study (Bonner and Moore, 1971) did fortuitously analyze one scenario that approximates the rate at which lead removal from gasoline actually occurred from 1973 to 1978. It is likely that the delays in the implementation of the various stages in the lead phasedown, even though they may not have actually reduced investments and operating costs associated with the standard, delayed them long enough to affect the present value of those costs as seen in 1971. Thus, it is likely that the cost estimates that were developed using the investment streams predicted by the studies of the unrevised 1973 regulations overestimated the

actual costs of the investment streams that occurred under the revised phasedown schedule.

### 2.3 ASSESSING THE EFFECTIVENESS OF EPA REGULATIONS LIMITING THE LEAD CONTENT OF MOTOR FUEL

In our previous work related to the cost-effectiveness of toxic substance regulations,<sup>27</sup> we explained how, owing to the difficulties in applying classically defined cost-effectiveness analysis in these cases, we would define "effectiveness" to mean any measure that could be developed of the beneficial effects of the regulations on the public health or welfare, measured in their natural units (as opposed to being presented in a monetized form). The following discussion of the effectiveness of the lead-in-fuel regulations will, first, present the nature of the evidence used by EPA to justify the standard on public health grounds and, second, will present information which has subsequently become available relating to the health and health-related benefits of the lead-in-fuel standards.

#### 2.3.1 Health Benefit Studies of the Lead-in-Fuel Regulations

In Section 2.1, we reported that EPA was not able to develop any quantitative measures of the effect of a reduction of the lead content in fuel on the health of children exposed to lead dust, or to any other segment of the population. Instead, EPA developed extensive qualitative arguments which identified lead from gasoline combustion as an important source of lead exposure to urban children, a group known to be at high risk of adverse effects from lead exposure.

The major document used by EPA to support their contention that a limitation on lead in gasoline would reduce the adverse effects of lead on city children was a position paper drafted by the agency during the regulatory proceedings.<sup>28</sup>

This paper summarized the state of knowledge regarding the health effects of lead exposure, emissions of lead into the atmosphere, the relationship between blood and air-lead levels, and the relative importance of various routes of exposure as sources of lead intake in urban children. Much of this information had been summarized in a major study of environmental lead contamination by the National Academy of Sciences, published in the previous year.<sup>29</sup>

The major threads in EPA's argument, as summarized in the preamble to the lead-in-fuel standard, were:

- lead from gasoline combustion was estimated to account for 90% of all man-made lead emissions;

<sup>27</sup> Feasibility of Measuring and Comparing ( op. cit. ), page 1.

<sup>28</sup> "EPA's Position on the Health Implications of Airborne Lead", 1973.

<sup>29</sup> National Research Council, National Academy of Sciences, Lead: Airborne Lead in Perspective, (Washington, D.C., 1972).

- lead from gasoline combustion had been demonstrated to be a major source of lead in urban dust;
- lead levels in urban air were known to be elevated, and this elevation could often be shown to be correlated with elevated lead levels in the blood of urban populations. Elevated blood lead levels had been correlated, in several studies, with the incidence of lead poisoning;
- while the ingestion of lead-containing paint chips was known to be a major source of lead intake in many children with symptoms of lead poisoning, no such ingestion could be demonstrated in at least 50% of such cases, indicating that some other source (such as lead-containing soil or airborne dust particles) was responsible for the poisoning; and,
- EPA also pointed out that recently-obtained evidence indicated that lead exposure levels which were previously thought to be harmless, were now thought to be associated with sub-clinical neurological defects and behavioral disorders, thus accentuating the need for stringent control on all sources of lead exposure.

In summarizing their position, EPA stated "...no single study has collectively interrelated all steps in the exposure process to conclusively prove or disprove the hypothesis...[that lead in gasolining is responsible for lead-related health effects in urban children]."<sup>38</sup> As was discussed in Section 1, when the regulation was challenged, the U.S. Court of Appeals for the District of Columbia upheld EPA's position that, despite their inability to conclusively establish a quantitative relationship between lead exposure from gasoline and lead poisoning, there was sufficient evidence available to justify limiting the amount of lead-containing additives that could be used in automotive fuel.

Since the original lead-in-fuel regulation was promulgated, much research has been conducted on the relationship between lead levels in air, water and soil, blood-lead levels in exposed populations and the incidence of lead-related disease. Much of this work has been summarized and reviewed in the Criteria Documents for lead pollution of air and water developed for

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<sup>38</sup>38 Federal Register 33737, December 6, 1973.



EPA,<sup>31,32</sup> and in a major analysis of the problems of environmental lead pollution by the National Academy of Sciences.<sup>33</sup> At this time, there is still no consensus as to how to relate changes in the amounts of lead emitted by various sources to changes in the health status in exposed populations. Studies have clarified the relationship between lead emission from various sources and levels in the ambient environment, and also the relationship between ambient lead exposures, the intake of lead by the exposed populations, and changes in blood lead levels. The major problems which have to be resolved, if quantitative assessment of the health effects of regulations controlling lead in the environment are to be developed, have to do with determining, for specific populations, the relative importance of various sources of exposure in determining the severity of lead-induced disease, and the general problem of relating time and intensity patterns of exposure to the nature and severity of these health effects.

The discussion which follows will summarize some of the recent research that enables us to develop quantitative measures of the effectiveness of the lead-in-fuel regulation, such as changes in the amount of lead emitted, changes in urban air lead levels, and the effect of reduction in lead fuel use on blood-lead levels in city children.

#### 2.3.2 Health-Related Effectiveness Measures for the Lead in Fuel Regulation

In our previous cost-effectiveness feasibility work, we explained how, when direct measures of the health effects of a regulation could not be developed, indirect measures could often be used to compare the degree of effectiveness of two or more regulations, if the units of measurement were the same or similar. This is particularly true in the case of lead where although direct measures of health effects of the various lead regulations are not available, indirect measures can be developed which relate more or less directly to the production of health effects. For example, in the case of both the ambient standard for lead in air and the lead-in-fuel regulation, estimates of the reduction in lead emission attributable to the standard can be made. For the ambient air lead standard, the lead-in-fuel standard, and the primary drinking water standard for lead, by using a few simple assumptions about exposure levels and absorption efficiencies, it is possible to make very rough comparisons between the three standards as to the reductions in the amount of lead absorbed by the exposed populations brought

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<sup>31</sup>U.S. Environmental Protection Agency, Office of Research and Development, Air Quality Criteria for Lead, (Washington, D.C., 1977) EPA #600/8-77-017.

<sup>32</sup>U.S. Environmental Protection Agency, Criteria and Standards Division, Office of Water Planning and Standards, Lead, Ambient Water Quality Criteria, (Washington, D.C., 1979).

<sup>33</sup>National Research Council, National Academy of Sciences, Lead in the Human Environment, (Washington, D.C., 1980).

about through regulation. Finally, by making additional assumptions about average blood-lead level distributions, it is possible to roughly estimate changes in the distribution of blood lead levels over time, and changes in the number of persons at risk of the various lead-related diseases. These techniques will be discussed in more detail in section 2.3.3. First, we will review the available information about health-related effectiveness measures for the lead-in-fuel regulations.

Changes in Lead Alkyl Production. Because total automobile lead emissions are roughly proportional to the lead content in gasoline, measuring changes in the lead content of all the gasoline manufactured in the U.S. over time is one good way to measure the impact of the lead-in-fuel standard on lead emissions. Exhibit 2-11 contains data on the trend in total lead usage in the manufacture of gasoline in the U.S. and in the average lead content of gasoline from 1970 to 1978. The reduction in the total lead content in gasoline, and in the average lead content in fuel can be clearly seen in these data. It should be noted that the average lead content of fuel had begun to decline around 1970, almost 4 years before the actual promulgation of the lead-in-fuel regulation. This is not surprising, since, as was discussed in Sections 2.1 and 2.2, the problem of lead pollution had become a serious public health issue in the middle 1960s, so much so that the petroleum industry was already planning strategies to produce unleaded gasoline and estimating the costs of doing so.

If one wished to calculate the actual "benefits" or effectiveness of the standard, in terms of reduced lead content in gasoline, one could simply estimate what the trend in lead usage would have been in the absence of regulation and calculate the difference for each year after the imposition of the standard. One interesting feature of the data is it can be seen that, as of 1978 at least, the "goal" of the regulation, of reducing lead usage 60-65% from the 1971 level, had not yet been accomplished. Judging from the trend in the data, however, it appears that full compliance with the 0.5 gm/gallon standard, which was scheduled to occur late in 1980, could easily achieve this objective.

Changes in Lead Emissions from Automobiles Due to the Lead-in-Fuel Standard. EPA estimated that in 1975, total lead emission from fuel combustion was 142,000 metric tons.<sup>34</sup> Recently, this estimate has been called into question, on the grounds that the data on which it was based, namely, total production of lead additives in the United States, did not take into account the fact that about 13% of this production was manufactured for export.<sup>35</sup> There are few reliable estimates of the amount of lead emitted from automobiles prior to 1975 for this and related reasons. Detailed estimates of lead emissions and of the amount of lead emitted from 1975 onward

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<sup>34</sup> Air Quality Criteria for Lead ( op. cit.), p. 5-3

<sup>35</sup> Provenzano, G., "Motor Vehicle Lead Emissions in the United States: An Analysis of Important Determinants, Geographic Patterns and Future Trends," Air Pollution Control Association Journal, 28(12), 1193-1199, 1978.

## EXHIBIT 2-11

TRENDS IN THE TOTAL LEAD CONTENT OF GASOLINE AND AVERAGE LEAD  
CONTENT OF THE TOTAL GASOLINE POOL, 1970-1978

| <u>Year</u> | <u>Total Lead Content</u><br><u>(millions of grams)</u> | <u>Average Lead Content</u><br><u>(gm/gal)</u> |
|-------------|---------------------------------------------------------|------------------------------------------------|
| 1970        | 211.4                                                   | 2.39                                           |
| 1971        | 201.0                                                   | 2.17                                           |
| 1972        | 205.5                                                   | 2.11                                           |
| 1973        | 205.5                                                   | 2.04                                           |
| 1974        | 176.0                                                   | 1.79                                           |
| 1975        | 158.5                                                   | 1.58                                           |
| 1976        | 169.8                                                   | 1.61                                           |
| 1977        | 160.8                                                   | 1.48                                           |
| 1978        | 137.6                                                   | 1.25                                           |

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Source: SRI International, Chemical Economics Handbook.

have been made, however, using a sophisticated procedure that takes into account fleet characteristics, driving conditions, and the effects of regulatory programs on the consumption of leaded gasoline. Exhibit 2-12 summarizes the results of that analysis, for several regulatory scenarios. It can be seen that both EPA regulations having to do with lead in fuel have the potential for substantially reducing the amount of lead emissions. With both the fuel lead phase-down and the regulations requiring the production of adequate amounts of fuel to supply catalyst-equipped cars in effect (the present situation), it is predicted that lead emissions will be reduced more than 95%, to about 5,000 tons per year, by the year 2000. The unleaded fuel production requirement alone would also accomplish this reduction, but somewhat more slowly, assuming the rate of fleet replacement stays near present levels. This is because, independent of the lead content of leaded fuel, by the later 1980s, it is expected that few cars requiring leaded fuel will still be in use.

If the unleaded fuel production requirement were repealed in 1980 (if, for example, a lead-tolerant catalyst system were developed), it was predicted that the lead phase-down alone would result in reduction of lead emission to about 30 thousand metric tons in 1990, which represents a reduction of about 75 percent compared to 1975 levels. After this, lead emission would rise slowly parallel with the demand for gasoline. If both the fuel lead phase-down and the unleaded fuel production requirements had been repealed in 1980, emission rates would be predicted to rise dramatically back to the 1975 level by the year 2000.

In order to calculate the amount by which lead emissions are being reduced by the lead-in-fuel standards, it was necessary to postulate a baseline scenario, which described what the lead content of gasoline would have been in the absence of the lead standard. We chose to analyze three alternative baseline assumptions, the first being that, in the absence of the lead-in-fuel standard, lead usage (and hence lead emissions) would have continued to increase between 1970 and 2000 at about 5% per year, as they had between 1965 and 1970, prior to the imposition of the lead standard. The second scenario assumed that lead usage would increase at a rate of 2% per year between 1970 and 2000, which is roughly equivalent to the long-term growth rate in lead additive usage between 1955 and 1970. The final scenario postulated that there would be no growth in the use of lead additive (0%/year) in the absence of the standard. The last scenario, assuming that gasoline demand will continue to increase, implies that the lead content in gasoline would decrease, even in the absence of regulation. Throughout the analysis it was assumed that 12.5% of U.S. lead fuel additives would be exported and that 80% of the lead additives used in the U.S. would eventually be emitted into the air. The results of this analysis are summarized in Exhibit 2-13.

It can be seen that the amount of lead emission reduction brought about by the lead-in-fuel regulations depends to a great extent on the assumptions made about the trend in lead use in the absence of regulation.

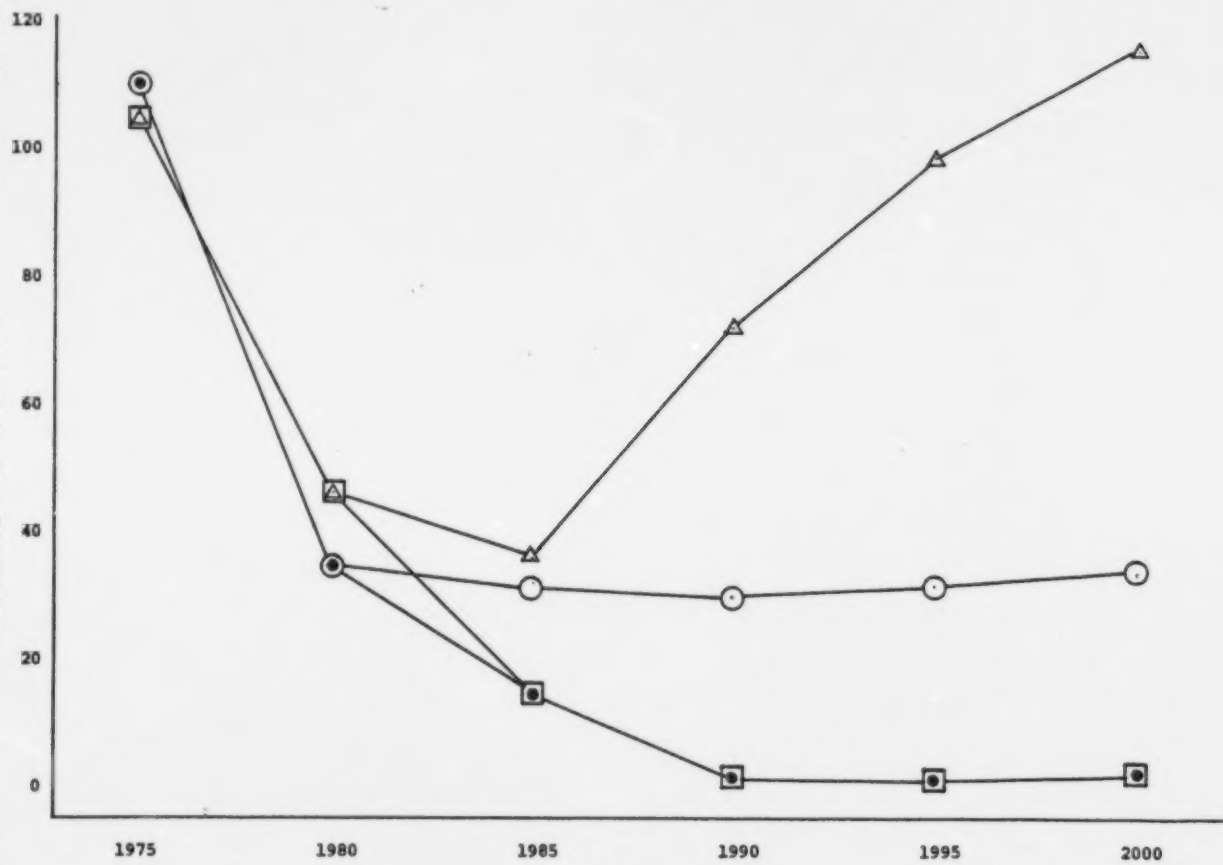


EXHIBIT 2-12

CHANGES IN MOBILE SOURCE LEAD EMISSIONS OVER  
TIME UNDER VARIOUS REGULATORY SCENARIOS

Lead Emissions,  
Thousands of  
Metric Tons/Year

- — ● = Fuel lead phasedown, unleaded fuel requirements in effect
- — ○ = Fuel lead phasedown only, no unleaded fuel requirement
- — □ = Unleaded fuel production requirement only, no phasedown
- △ — △ = No lead regulation after 1980



Source: Provenzano, G., "Motor Vehicle Lead Emissions in the United States: An Analysis of Important Determinants, Geographic Patterns, and Future Trends," Air Pollution Control Association Journal, 28(12), 1193-1199, 1978.

## EXHIBIT 2-13

REDUCTION IN CUMULATIVE LEAD EMISSIONS  
BROUGHT ABOUT BY THE LEAD-IN-FUEL REGULATIONS

| Baseline Assumption<br>Annual Growth in Lead<br><u>Usage Without Regulation</u> | Cumulative Reduction in Emissions<br>(thousands of metric tons) |                  |                  |
|---------------------------------------------------------------------------------|-----------------------------------------------------------------|------------------|------------------|
|                                                                                 | <u>1971-1980</u>                                                | <u>1971-1985</u> | <u>1971-2000</u> |
| 0 percent lead growth                                                           | 465                                                             | 1,042            | 3,033            |
| 2 percent lead growth                                                           | 618                                                             | 1,401            | 4,626            |
| 5 percent lead growth                                                           | 817                                                             | 1,950            | 8,123            |

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Source: Adapted from Provenzano, G., "Motor Vehicle Lead Emissions in the United States: An Analysis of Important Determinants, Geographic Patterns and Future Trends," Air Pollution Control Association Journal, 28(12), 1193-1199, 1978.

Changes in Air Lead Levels Brought about by Lead-in-Fuel Regulations.

Because automobile lead emissions account for the bulk (as much as 90%) of urban lead emissions, and because lead use for gasoline has been decreasing rapidly since around 1970, it is not surprising that measured urban air lead levels have also been decreasing.

The major source of information concerning air lead levels on a national basis is the National Air Sampling Network, which has been operating over 300 air sampling stations throughout the U.S. since 1966. Data from this sampling network indicates that average urban air lead levels decreased in the years 1970-1974, after having increased slowly over the five previous years.<sup>36</sup> After 1974, sampling procedures and locations were changed, and subsequent air lead measurements are not comparable with those previously taken. Therefore, at present, a complete time-series study of U.S. urban air lead levels is not possible using this data source. Between 1970 and 1974, average urban air lead levels decreased about 25%, from around 1.2  $\mu\text{g}/\text{M}^3$  in earlier years to 0.9  $\mu\text{g}/\text{M}^3$  at the end of the period.

Although recent data are not available at the national level, several studies have analyzed urban air lead levels after 1974 for individual cities in the U.S. For example, Hoggan, et al.<sup>37</sup> studied time trends in air lead levels and the relationship between these levels and the consumption of leaded gasoline in the Los Angeles Basin. Their data clearly demonstrate a significant reduction in air lead levels at 4 sampling stations in Los Angeles beginning in 1971. The average reduction in annual mean lead concentration at these stations between 1971 and 1977 was 54%, with the 1971 average lead values ranging from 3.3 to 8.1  $\mu\text{g}/\text{M}^3$  and the average 1977 values ranging between 1.7 and 4.0  $\mu\text{g}/\text{M}^3$ . Two other stations, not operating in 1971, showed significant decreases in lead levels between 1972 and 1977. In addition, it was found that the seasonal (winter-summer) differences in air lead levels were highly correlated with the lead consumption; the air lead levels at several monitoring stations were found to be a simple constant function of city-wide leaded fuel purchases.

A similar pattern of gradually decreasing air lead levels can be seen in the limited monitoring data available from New York City.<sup>38</sup> Between 1970 and 1976, average quarterly air lead levels have decreased almost 50% from

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<sup>36</sup>U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, National Trends in Trace Metals in Ambient Air 1965-1974, (Research Triangle Park, N.C., 1977) EPA-450/1-77-003.

<sup>37</sup>M.C. Hoggan, et al., "Motor Vehicle Emission and Atmospheric Lead Concentration in the Los Angeles Area", Journal of the Air Pollution Control Association, 28(12), 1200-1206, 1978.

<sup>38</sup>I.N. Billick, A.S. Curran, D.R. Shier, "Analysis of Pediatric Blood Lead Levels in New York City for 1970-1976", Environmental Health Perspectives, 31, 183-190, 1979.

about 1.6  $\mu\text{g}/\text{M}^3$ , depending on the season of the year. Subsequent work, which we will discuss below, indicated that the pattern in air lead observed in New York City was closely correlated with sales of leaded gasoline and, more importantly, that both of these variables were extremely well-correlated with observed blood lead levels in children.

Taken together, these studies clearly indicate that a decrease in urban air lead levels has occurred as a result of the decreased use of lead fuel additives. The reduction in total air lead levels are relatively large and it is to be expected that reductions in the levels of lead in urban dust will be correspondingly reduced. Thus, two major sources of exposure to lead in the urban environment appear to have been greatly reduced by the lead-in-fuel regulations, and further reductions can be expected.<sup>33</sup> These reductions in air lead levels could be used to compare the lead-in-fuel regulations with the ambient air lead standard, which we have analyzed previously.

Changes in Blood-Lead Levels Brought About by the Lead-in-Fuel Regulations. In our analysis of the ambient air lead standard and the primary drinking water standard for lead, the final step in the procedure for developing health-related measures of benefits/effectiveness was the estimation of changes in the distribution of blood lead levels brought about by these regulations. In that case, the analysis was highly imprecise, and depended heavily on assumptions made about the "background" distribution of blood-lead levels, the relationship between air and water-borne exposure, the intake of lead by the exposed population, and the relationship between lead intake and blood-lead levels.

In the case of the lead-in-fuel regulations, the analysis is greatly simplified by the availability of several recent studies which actually demonstrate a relationship between leaded fuel consumption, air-lead levels, and the distribution of blood-lead levels in urban children. Thus, by drawing careful causal inferences from the statistical relationships between these variables, it is possible to attribute observed changes in blood-lead levels directly to the lead-in-fuel regulations. Before discussing the studies in detail, it should be pointed out that there are great difficulties involved in studies of this type, not the least of which is the shortage of adequate data, and that numerous investigations have failed to disclose consistent relationships between measured lead exposures and blood-lead levels. It is our belief, however, that as more data becomes available and better analytic methods are developed, many of the factors which have confounded previous studies will be overcome, and the complexities of the relationships between exposure and blood-lead levels will be more widely understood.

By far, the most extensive source of information concerning the relationship between blood-lead levels in children and gasoline lead usage are from studies conducted under the direction of Dr. Irwin Billick of the Office of Environmental Hazards at the Department of Housing and Urban Development. The most striking of these studies dealt with the relationship between

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<sup>33</sup>See Provenzano, op. cit.



gasoline lead usage, air lead levels and blood-lead levels in New York City.<sup>40</sup> These studies, based on comparison of total gasoline lead usage in the New York Metropolitan area, the previously mentioned air-lead monitoring data, and the results of New York's extensive blood-lead screening program which involved more than 180,000 children, demonstrate a remarkable correlation between lead usage, air lead levels, and pediatric blood-lead levels (Exhibit 2-14). Not only does the overall downward trend in geometric mean blood-lead levels for both Blacks and Hispanics (those groups most likely to experience high lead exposure) closely track the downward trend in lead usage, but the seasonal patterns in gasoline usage are clearly paralleled by seasonal changes in blood-lead levels. While other possible explanations exist for the pattern in blood-lead levels (the seasonal pattern may reflect children's tendency to spend more time out of doors in the summer, and the steady downward trend might be due in part to New York City's aggressive program to reduce lead poisoning from paint in substandard housing) it would be remarkable that such a close correlation exists between lead usage and blood-lead levels, were they not causally related.

In addition, studies of similar data from other cities tend to confirm the correlation between leaded gasoline usage and blood-lead levels in children. Two recent studies of this relationship in data from Louisville, Kentucky and Chicago, Illinois, for the period 1974-78, for example, found that the correlation between pediatric blood-lead levels and lead usage was very strong, almost as strong as in the New York data.<sup>41</sup> Another similar study of data from Columbus, Ohio, found that the correlation between blood lead and lead usage was weaker.<sup>42</sup> This result was probably due in part to the poor quality of the blood level and gasoline usage data available for Columbus.

Taken together, the results of these studies strongly suggest that there is a causal relationship between the use of lead in gasoline and children's blood-lead levels in urban areas. As we will now discuss, this provides a useful basis upon which to develop measures of the effectiveness or "benefit" or the lead-in-fuel standard.

### 2.3.3 Feasibility of Developing Measures of the Changes in Public Health and Welfare Brought About by the Lead-in-Fuel Regulations

In comparing the effectiveness of two or more regulations, it is of course desirable to be able to develop effectiveness measures which

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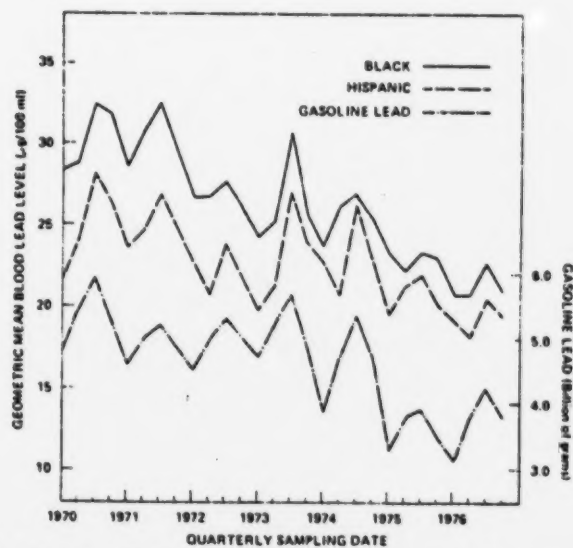
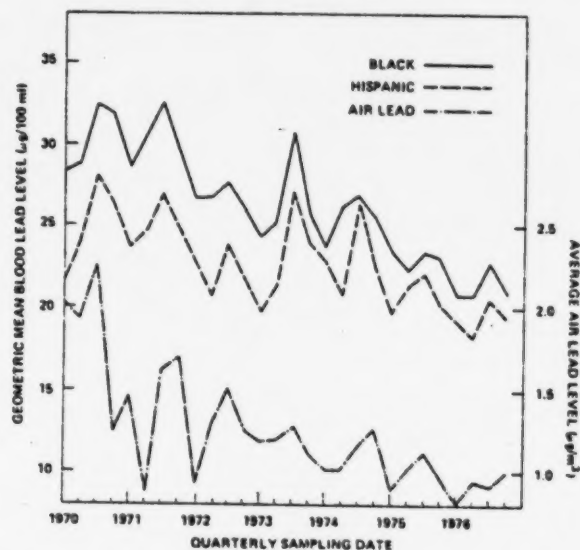
<sup>40</sup>"Analyzing Pediatric Blood Lead..." (op. cit.) and I.H. Billick, A.S. Curran and D.R. Shier, "Relation of Pediatric Blood-Lead Levels to Lead in Gasoline," Environmental Health Perspectives, 34, 213-217, 1980.

<sup>41</sup>MITRE Corporation, "Statistical Analysis of Blood-Lead Levels in Relation to Gasoline Lead, Louisville, Kentucky," Working Paper #80W00466, September 1980; Research performed under contract #68-01-5865 to the U.S. Environmental Protection Agency.

<sup>42</sup>MITRE Corporation, unpublished preliminary results, December 1980.

## EXHIBIT 2-14

THE RELATIONSHIP BETWEEN AIR LEAD LEVELS,  
GASOLINE LEAD USAGE AND CHILDREN'S BLOOD LEAD LEVELS  
IN NEW YORK CITY, 1970-1977



Source: I. H. Billick, A. S. Curran, and D. R. Shier, "Relation of Pediatric Blood-Lead Levels to Lead in Gasoline," Environmental Health Perspectives, 34, 213-217, 1980.

actually measure changes in the health status of the exposed populations. In our previous work on the Primary Drinking Water Standard for Lead, we indicated that this was not possible, because even if changes in blood-lead distributions could be estimated (which we did), there was no simple relationship between the changes in blood-lead distribution and the incidence of the various lead-induced disease states. Further, it is very difficult to relate the incidence of these disease states to readily comparable units of health impact, such as changes in mortality or morbidity. This state of affairs still exists, so there is in fact no good way to measure the benefits/effectiveness of the lead-in-fuel regulations in units that directly measure changes in health status.

This does not mean that quantitative comparison of the effectiveness of this regulation with other regulations, especially those which reduce lead exposure, are impossible. In analyzing the effectiveness of the lead drinking water standard, we pointed out that the changes in blood-lead distribution, which we estimated would occur as a result of the standard, could be interpreted in terms of the number of persons at risk of the various lead-induced diseases, which are known not to occur (or rarely to occur) below certain "threshold" blood-lead levels.<sup>43</sup> While we have our reservations about the accuracy of the "threshold" model as an adequate picture of the way in which lead-induced diseases occur, we do see it as a useful tool in analyzing the health impacts of reducing lead exposure. For example, by postulating a blood-lead distribution (which is usually log-normal in the general population), we could predict the number of children at risk of a given syndrome, such as lead-induced anemia, or peripheral neuropathy, over time, on the basis of Billick's New York Study, or the MITRE Louisville Study. We could then compare this result to what we think the blood-lead distribution would have been in the absence of the lead-in-fuel standard to obtain an estimate of the reduction in the number of children at risk of the various lead-induced diseases brought about by the lead-in-fuel regulation.

This measure, while perhaps not useful for comparing the effectiveness of the lead-in-fuel standard to regulations dealing with benzene or asbestos, could be used to make direct comparisons between the lead-in-fuel standard and any other standard which has reduced children's lead exposure. Thus, this health-related measure (changes in blood-lead levels) may be a generally useful tool for comparing lead regulations, and is probably as close as one can get to a direct measure of the health impacts of such standards, given the present state of knowledge.

#### 2.4 COST-EFFECTIVENESS OF THE LEAD-IN-FUEL REGULATIONS

In the previous two sections of the report, we derived estimates of the economic impacts of the lead-in-fuel regulations (both the unleaded fuel requirements and the lead-content phasedown) and we discussed the nature and magnitude of the risks to human health that could be averted by these

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<sup>43</sup>National Academy of Sciences, Lead in the Human Environment ( op. cit. ), p. 135.

regulations. Two important features of these analyses need to be reviewed before embarking on attempts to develop comparison of the costs and effectiveness of these regulations. First, it must be remembered that the estimates of economic impacts that were developed included both monetary (e.g., investment and operating costs) and non-monetary (e.g., increased oil and energy consumption) elements. While it might be possible with, some effort to assign monetary values to the latter impacts, it is not clear that doing so would be consistent with the assumptions implicit in the individual analyses (that is, the analyses may have been based on different crude oil and energy costs than actually occurred). There are in addition other non-monetary impacts which are even more difficult to quantify, either by their nature, or because they were not dealt with in any quantitative way. These include effects on the regional distribution of refineries and the possibility of the closure of certain small refineries or distributorships (with the attendant loss of employment and other associated impacts).

The second point to be kept in mind is that, given the present state of knowledge about lead-induced illness, it is not possible to develop quantitative estimates of actual changes in health status that would be brought about as a result of lead-in-fuel standards. As we discussed in Section 2.3, it is relatively easy to estimate the changes in lead additive consumption, lead emissions from automobiles, and even in the distribution of blood lead levels that have been brought about by the lead-in-fuel standards, but no dose-response functions exist that allow us to translate any of this information into conventional measures of health impact, such as morbidity or mortality statistics, or even cases of disease.

These two factors make the development of any simple, single-valued measure of cost-effectiveness for this regulation quite difficult. As we will see however, it does not prohibit meaningful comparisons from being made between this and other toxic substance regulations, especially those which limit lead exposure.

#### 2.4.1 Costs and Effectiveness of the Lead-in-Fuel Regulations

Because single-valued measures of the cost-effectiveness of the lead-in-fuel regulations cannot be developed, we will instead present comparisons between the economic impacts of the standard and some of the health-related benefit measures that were discussed in Section 2.3. One of the more interesting comparisons that can be made is the comparison between the economic impacts of the standard and the reductions in the amount of lead emissions over time brought about by the lead standards. This comparison is possible because we have detailed predictions about the regulation of lead emissions that will occur as a result of the enforcement of the unleaded fuel requirement and the lead phasedown.<sup>44</sup> The methodology used to develop the estimate of the economic impact of the lead-in-fuel standard was discussed in section 2, and will not be repeated here.

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<sup>44</sup>Provenzano, op. cit.



Exhibit 2-15 compares the reduction in lead emissions brought about by the lead-in-fuel standard to the economic impacts of the standards as discussed in Section 2.2.

#### 2.4.2 Marginal Costs and Effectiveness of the Lead-in-Fuel Regulations

In principle the marginal costs and effectiveness of the lead-in-fuel regulations would be relatively easy to determine, although a relatively intensive effort might be required to actually do the analysis. In attempting to measure the marginal economic impacts of some change in the regulations, much would depend upon which characteristics of the regulations would be varied; that is, there are a number of ways to "tighten" or "loosen" the regulations. One could change the timing of the lead phasedown, increase or decrease the final level of lead allowable in fuel, or repeal the phasedown entirely and allow the unleaded fuel production regulations to gradually reduce the use of lead additives by itself. Some of these scenarios have already been analyzed by one or more of the studies,<sup>45</sup> and the results could probably be updated and adapted to produce marginal impact curves for changes in various aspects of the standards.

The same situation of course exists with regard to "effectiveness". Analyses could be conducted to measure the effectiveness of the regulations at various control levels over time. Some sensitivity analyses like this having to do with the effect of different regulatory scenarios on the amount of lead emitted by automobiles have already been performed.<sup>46</sup> At the present time, it would appear that similar analyses may soon become feasible using observational data concerning the relationships between leaded fuel consumption and urban blood lead levels in children. One could, for example, use these studies to predict the changes in blood lead levels, and hence in the number of children at risk of lead-induced disease, brought about by incremental changes in the timing and degree of lead usage reductions.

It would also be possible to use studies of this kind to produce something that would look a lot like a conventional cost-effectiveness measure. However, such a measure would be multi-dimensional, because many of the elements of both the "cost" and "effectiveness" side are not readily comparable. For example, a measure which compared, or took the ratio of, the reduction in emissions of lead to the total increase in refinery costs brought about by the standards would not capture such important effects as the increases in fuel costs to society, increases in energy and oil consumption, changes in refinery viability and loss of employment and output due to refinery shutdowns. On the effectiveness side, such a measure, without reference to the geographical pattern of lead emissions, the lead exposure of sensitive populations (urban children) and the relationship between the length and intensity of exposure to the magnitude of health effects, would still require decision makers to make complex value judgements in comparing policies, and could deprive them of much useful information required to do so.

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<sup>45</sup>See Bonner and Moore, 1971, op. cit., for example.

<sup>46</sup>Provenzano, op. cit.

# EXHIBIT 2-15

## COMPARISON OF REDUCTION IN LEAD EMISSION AND ECONOMIC IMPACTS OF THE LEAD-IN-FUEL REGULATIONS

| Reduction in Lead Emissions<br>To the Atmosphere, Total |                      |                      | Monetary Costs -<br>Investment Plus<br>Operating Costs Plus<br>Costs of Distribution |                        | Non-Monetary Impacts                                    |                                                                                    |
|---------------------------------------------------------|----------------------|----------------------|--------------------------------------------------------------------------------------|------------------------|---------------------------------------------------------|------------------------------------------------------------------------------------|
| 1971-1980                                               | 1971-1985            | 1971-2000            | 1971-1980                                                                            | 1971-1975              | Oil Consumption (thousands<br>of barrels per day, 1980) | Increased Energy<br>Consumption (thousands of<br>barrels oil equivalent/day, 1980) |
| (Thousands of metric tons)                              |                      |                      | (billions of 1980 dollars)                                                           |                        |                                                         |                                                                                    |
| 465 <sup>a</sup> /                                      | 1,042 <sup>b</sup> / | 3,033 <sup>c</sup> / | 3.6-4.8 <sup>d</sup> /                                                               | 5.5-7.7 <sup>d</sup> / | 250 (70-567) <sup>e</sup> /                             | 70 (50-111) <sup>e</sup> /                                                         |
| 618 <sup>b</sup> /                                      | 1,401 <sup>b</sup> / | 4,626 <sup>b</sup> / |                                                                                      |                        |                                                         |                                                                                    |
| 817 <sup>c</sup> /                                      | 1,950 <sup>c</sup> / | 8,123 <sup>c</sup> / |                                                                                      |                        |                                                         |                                                                                    |

<sup>a</sup>/Assumes 0 percent annual growth in use of lead additives in absence of standard.

<sup>b</sup>/Assumes 2 percent annual growth in use of lead additives in absence of standard.

<sup>c</sup>/Assumes 5 percent annual growth in use of lead additives in absence of standard.

<sup>d</sup>/Best estimate plus some fraction of 2.2 billion dollars, cost of 3-grade distribution system.

<sup>e</sup>/Figures in parentheses represent range of estimates.

If one still wished to calculate the amount of lead emissions prevented per dollar spent (investment and generating costs), such a calculation could be performed using the cost and emission reduction estimates contained in Exhibit 2-15. Such a calculation would indicate that, depending upon the baseline assumptions chosen relating to the rate of increase in lead usage in the absence of any lead-in-fuel regulations, the costs incurred between 1971-1980 per ton of emissions presented in those years would range between 4400 and 10,000 dollars (1980 price levels). It should be noted that the cost-effectiveness measures calculated in this way, aside from having all of the weaknesses previously discussed, in addition would tend to overstate the cost per ton of reduced emissions (and underestimate cost-effectiveness) because it can be expected that a large portion of the investment undertaken in 1971-1980 also contributes to the refinery industry's ability to reduce lead usage in later years as well, and that this investment was undertaken in anticipation of the necessity for doing so.

#### 2.4.3 Uncertainty in the Costs and Effectiveness of the Lead-in-Fuel Regulations

It is difficult to place confidence intervals around the estimates of cost and effectiveness that can be derived from the various studies of the lead-in-fuel regulations. In the case of the cost estimates, the various studies produce a range of estimates that could be regarded as reflecting the degree of uncertainty that is inherent in the important modelling assumptions and techniques used to estimate these impacts. In the case of the effectiveness estimates, especially the direct studies of relationships between lead usage and blood lead levels, it might be possible to estimate the statistical uncertainty associated with these relationships and use that as an indication of the degree of uncertainty in the effectiveness measures.

In light of the difficulty involved in developing quantitative measures of uncertainty associated with the cost and effectiveness estimates for the lead-in-fuel standard, we would advocate a strategy in using these measures that would recognize that it may be difficult to make "close calls" based on the results of available data. Based on our feelings about the nature of the available information, we would suggest that the following procedure be adopted. If, in comparing two or more of the various lead regulations, the decision maker finds that any measure of cost or effectiveness differs among the various regulation by 50 percent or less, it should be assumed, in the absence of further data, that the regulations are essentially undistinguishable along that dimension of cost or effectiveness. If regulations are found to differ in terms of cost or effectiveness by between 1.5 and 2 fold, and if the measures in question contributes in an important way to the total costs or effectiveness of the regulations, we would suggest that, before deciding that one measure was superior to another, that the original studies upon which the cost or effectiveness measure are based be reevaluated to determine the likely precision of the results. Only if costs or effectiveness measures differ by 2-fold or more would we be comfortable in saying that one measure was actually superior to another. Even using these rather severe evaluation criteria, we believe it is highly likely that, if detailed cost-effectiveness comparisons were made of the various lead regulations, one or more of the standards might be found to clearly dominate

one or more of the others, owing to the wide difference in costs and effectiveness between the standards.

#### 2.4.4 Comparing the Cost-Effectiveness of the Lead-in-Fuel Standard With Other Regulations

Since it is not possible to generate conventional measures of the health impacts of the lead-in-fuel standards, it would be difficult to compare its effectiveness, in other than a most general way, to that of most other toxics regulations. It would be possible, for example, to compare reductions in total populations at risk (of whatever disease) between the lead-in-fuel standard and other regulations, but that would be useful in making policy choices only in situations where there was very little other information available about the nature of the health effects involved.

There is far more potential for making well-informed cost-effectiveness comparisons between these regulations and others which limit population exposure to lead. One would still be left with the problem of multidimensional measures of economic impacts and effectiveness measures, but it is likely that the effectiveness of lead regulations can be compared in terms of changes in blood lead levels brought about over time, and the corresponding reductions in population at risk of the various lead-induced diseases. One still would have to somehow compare changes in populations at risk of lead neuropathy with reductions in populations at risk of kidney damage, but at least the comparison is between neuropathy vs. neuropathy and kidney damage vs. kidney damage, rather than neuropathy vs., for example, lung cancer or dermatitis.

Only a moderate amount of effort would be required to extend our work on the ambient air lead standard, the lead drinking water standard and these regulations to facilitate such comparisons. Again, fine distinctions may not be possible, but with commensurable effectiveness measures, and a reasonable weighting scheme for costs, it may well be that clear dominance can be established for one or more standards over others, and that marginal cost-effectiveness measures for the different lead regulations at different levels of control may be developed.



### 3. ASBESTOS

#### 3.1 INTRODUCTION

This chapter reviews two existing regulations that affect the manner in which asbestos is discharged into the environment. The first, National Emission Standard for Hazardous Air Pollutants (NESHAP), requires that millers, manufacturers, fabricators, and disposers of asbestos have "no visible" asbestos emissions to the outside air.<sup>1</sup> The NESHAP also restricts the use of asbestos for the surfacing of roadways, the spray application of friable insulation and other coating materials, and as molded or wet-applied insulation. Procedures for properly disposing of waste asbestos and for handling asbestos during renovation and demolition are also specified.

The second regulation, Effluent Limitation Guidelines for Asbestos Manufacturing Point Sources (Guidelines), defines the quality of water effluent required under "best practicable control technology" (BPT) and "best available technology economically achievable (BAT)."<sup>2</sup> Additionally, the Guidelines include Pretreatment Standards, New Source Performance Standards, and New Source Pretreatment Standards. BPT was required for existing sources by 1977, and BAT requirements are currently scheduled to become effective in 1984.

Other EPA asbestos related actions, not examined here, include the publication of an Ambient Water Quality Criteria Document for Asbestos<sup>3</sup> and three proposed rules under the authority of the Toxic Substances Control Act. The Clean Water Act requires the administrator to publish water quality criteria for toxic pollutants listed under Section 307(a)(1) of that Act, which includes asbestos. Water quality criteria are non-regulatory, scientific assessments of individual pollutants, and are mandated to reflect the latest scientific knowledge on their health and welfare effects. The information is used by states as the basis for adopting state water quality standards.

To assess the "cost-effectiveness" of listing asbestos as a toxic pollutant, one must examine the effects that the water quality criteria document had on state water quality standards. A hypothetical base case of states' "behavior" in the absence of the water quality criteria for asbestos is needed. Sufficient information is not readily available to assess the

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<sup>1</sup>40 CFR 61.20. Individuals may also comply by using specified air cleaning devices.

<sup>2</sup>40 CFR 427.

<sup>3</sup>EPA, Ambient Water Quality Criteria for Asbestos (Washington, D.C.: October 1980 [NTIS PB81-117335]).

impact that the criteria had on the quantity of asbestos emissions allowed by the states. Therefore, the water quality criteria for asbestos are not examined.

The proposed TSCA rules are:

- Asbestos-Containing Materials in School Buildings;<sup>4</sup>
- Asbestos; Reporting and Recordkeeping;<sup>5</sup> and
- Commercial and Industrial Uses of Asbestos Fibers.<sup>6</sup>

The first rule, School Buildings, is a response to the growing awareness that there are thousands of children, teachers, and staff exposed to asbestos fibers from friable asbestos insulation in school buildings. The proposed rule requires that steps be taken to identify friable asbestos materials in schools. A second rule, as yet not published, may require corrective actions be taken to remove the hazards identified under the first rule. The Department of Education is coordinating with EPA to provide grants and loans to assist state and local educational agencies in meeting the program objectives.<sup>7</sup> EPA's proposed School Buildings Asbestos rules are not examined here because the requirements for hazard reduction through the removal of asbestos containing material are as yet unspecified.

An asbestos reporting rule has been proposed to obtain data on the full life-cycle emissions of asbestos; production, manufacturing, consumer use, and disposal. Current statistics kept by the Bureau of Mines can reliably identify the uses of only about sixty percent of the total bulk asbestos imported and produced annually in the U.S.<sup>8</sup> The proposed reporting rule is to provide information enabling EPA to examine all asbestos emissions and exposures such that the most effective means of hazard reduction can be identified. The proposed Commercial and Industrial Use Rule will be one component in the coordinated control of all life-cycle asbestos emissions. This rule is not sufficiently developed to warrant examination here, however. Additionally, the existing NESHAP is being reviewed under the general directives of E.O. 12291, and new information obtained from the reporting rule may be useful for purposes of that review.<sup>9</sup>

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<sup>4</sup>45 FR 61966, Proposed Rule.

<sup>5</sup>46 FR 8200, Proposed Rule.

<sup>6</sup>44 FR 60061, Advanced Notice of Proposed Rulemaking.

<sup>7</sup>45 FR 61950, Notice of Proposed Rulemaking.

<sup>8</sup>46 FR 8201.

<sup>9</sup>Personal communication with Mr. Michael Laney, Research Triangle Institute.

The current development of the asbestos reporting rule underscores the need to approach the problem of asbestos hazards in a comprehensive manner. Asbestos is a widely used materials, the use of which presents many opportunities for human exposure. To effectively reduce the risks to human health posed by this substance the entire range of exposure reduction possibilities should be examined, including the potential control of production, manufacture, product use, and disposal. The most cost-effective strategy of asbestos control may include controls at all stages of asbestos production and use. Because there is currently insufficient data readily available to evaluate all the relevant risk reduction options for asbestos control, the degree to which the existing controls reduce the total risks from exposure to asbestos cannot be determined.

Neither the NESHP nor the Guidelines is based on numerical measures of asbestos emissions. Even when compliance is documented, actual asbestos emission reductions can only be estimated from engineering analyses. Consequently, the cost-effectiveness of the two regulations is reported as wide ranges.

It should also be noted that the standards examined here do not require the destruction of asbestos. For the most part, discharges to air and water are diverted to land disposal. The risk associated with asbestos land disposal depends on the form in which the asbestos is disposed (free fiber or bound in a matrix binder such as cement) and the manner of disposal. Over 95 percent of all discarded asbestos is disposed to land. The relative risk of air and water emissions (with the demonstrated likelihood of human exposure) to land disposal (with the potential for human exposure) is currently not known. This is an issue for the comprehensive examination of all asbestos exposures. The issue of appropriate land disposal is currently being addressed by EPA and is beyond the scope of this investigation.

Finally, this study does not include an examination of the cost-effectiveness of asbestos regulations promulgated by other agencies; most notably the Occupational Safety and Health Administration (OSHA) regulation for worker asbestos exposure. In many cases an individual piece of equipment may be needed to comply with both the EPA and OSHA requirements. This complicates the estimation of compliance costs because there is no unique way to allocate correctly these costs to one regulation or the other. Therefore, except as noted in the individual analyses, the cost of the EPA regulations are calculated assuming that all the costs of the necessary equipment are attributable to it. This results in an over-estimation of costs in several instances. One way to handle this joint-cost problem would be to examine together all the costs and benefits of the EPA and OSHA regulations whose equipment overlaps to get a single estimate of cost-effectiveness. The analysis of the OSHA requirements was beyond the scope of this study.

### 3.2 NATIONAL EMISSION STANDARD FOR HAZARDOUS AIR POLLUTANTS (NESHP)

#### 3.2.1 Introduction

Background. Section 112 of the Clean Air Act requires the Administrator of EPA to designate "hazardous air pollutants" for which national emission standards will be promulgated. On the basis of its known health effects,

asbestos was designated as a hazardous air pollutant in 1971 and national emission standards (NESHAP) for asbestos were promulgated in 1973.

Since 1973 the regulation has been revised several times and was the subject of a Supreme Court decision. It originally covered:<sup>10</sup>

- asbestos mills;
- nine different manufacturing industries;
- the demolition of structures that contain friable asbestos;
- spray on materials used for certain insulating and fire-proofing applications; and
- uses of asbestos tailings for surfacing roadways.

The regulation has since been amended to clarify some of its provisions and to add restrictions on:<sup>11</sup>

- renovation;
- manufacture of asphalt-concrete containing asbestos;
- manufacture of shotgun shells containing asbestos;
- fabrication of cement building products, friction products, and cement or silicate board;
- waste disposal practices; and
- spray uses of asbestos for purposes other than insulating and fire-proofing.

In 1978 the U.S. Supreme Court held that EPA did not have the authority to promulgate the asbestos work practice requirements.<sup>12</sup> Although legislative actions have been taken that authorize EPA to promulgate and enforce such requirements, EPA still needs to repropose the work practice provisions promulgated prior to the enactment of the 1977 Clean Air Act Amendments.<sup>13</sup>

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<sup>10</sup>Research Triangle Institute, Review of National Emission Standard for Asbestos (Research Triangle Park, N.C.: October 1981 [EPA Project Number 80/41]), p. 2-2.

<sup>11</sup> Ibid, pp. 2-2 to 2-12.

<sup>12</sup> Ibid, p. 2-12.

<sup>13</sup>For a more detailed description of the Supreme Court Decision see Adamo Wrecking Company v. United States and Ibid pp. 2-12 to 2-13.



The original NESHAP was the first EPA asbestos regulation. In support of that action, EPA prepared the Comprehensive Study of Specified Air Pollution Sources to Assess the Economic Impact of Air Quality Standards: Asbestos, Beryllium, Mercury<sup>14</sup> (Comprehensive Study). The report estimates the number of tons of asbestos emissions that would be prevented annually and the cost of compliance for a rule that was proposed at the time. A second EPA report presents a less comprehensive assessment of the costs and effectiveness of the amendments to the original standards.<sup>15</sup> Because the original proposal analyzed in the Comprehensive Study is very similar to the current requirements, the Comprehensive Study is used below as the basis of our analysis. This report does not analyze separately the amendments to the original regulation.

The NESHAP. Because of difficulties in measuring the concentration of airborne asbestos, standards were not based on the quantity of asbestos in point source emissions. EPA considered a technology-based approach to requiring emissions reductions, but because of the legal interpretation of the need to promulgate quantitative emission limits instead required "no visible emissions to the outside air" for the following industries:

- Asbestos milling; and
- Manufacturing, including textiles, cement products, fireproofing and insulating materials, friction products, paper, millboard, paints, sealants, plastics and rubber materials, and chlorine.

A fabric filter collection device (of certain design and operating specifications) was specified as acceptable for meeting the no visible emissions requirement. Additionally, the use of asbestos waste tailings for the surfacing of roadways and the production of friable asbestos insulation materials was restricted.

The Comprehensive Study of the regulation predicted that by 1977 nearly 6,000 tons of asbestos air emissions would be prevented annually at an annualized cost of \$2.2 million (1970 dollars). Emission reduction estimates were developed for six categories: milling; asbestos cement; floor tile; friction material; asbestos paper; and asbestos textiles. Over 85 percent of the total predicted emission reduction was accounted for in the milling category, although this category only accounted for eight percent of the total predicted annualized cost. The asbestos cement category accounted for nearly

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<sup>14</sup>Research Triangle Institute, Comprehensive Study of Specified Air Pollution Sources to Assess the Economic Impact of Air Quality Standards: Asbestos, Beryllium, Mercury (Research Triangle Park, N.C.: August 1972 [NTIS PB-222 85B]).

<sup>15</sup>Research Triangle Institute, Standards Support Document: Promulgated Amendments to the National Emission Standards for Asbestos (Research Triangle Park, N.C.: June 1978 [NTIS PB-283 661]).

45 percent of the predicted costs, but only accounted for four percent of the predicted emission reduction. Emission reduction and costs were not estimated for the fabricating industry, for use restrictions in road surfacing and insulating materials, and for proper waste disposal. The report did not include an assessment of the beneficial health effects likely to result from the predicted emission reduction.

The cost and emission reduction estimates made in the Comprehensive Study must be revised for several reasons:

- The standard actually promulgated varies slightly from the option analyzed in the 1972 report in that it allows more flexibility in the choice of control equipment needed to attain compliance.
- The Comprehensive Study predicted a five percent annual growth in domestic asbestos production from 1970 to 1977. Domestic production has actually declined substantially during that time. The estimates of both the costs and the tons of emissions prevented from milling must be revised to reflect this decreased level of production.
- The Comprehensive Study did not explicitly assess the potential growth (or decline) of the asbestos manufacturing categories. However, the cost estimates reflect a five percent annual increase in costs and emissions between 1970 and 1977. Current data suggest that portions of these categories have declined through the 1970s, and again the estimates must be revised to reflect this decreased level of production.

To examine the total cost-effectiveness of the regulation, the cost and emission reduction estimates should also be revised to include those industries and activities omitted from the EPA analysis. Sufficient data are not readily available to estimate the compliance costs and emission reduction for the industries not examined in the Comprehensive Study. Therefore, analysis of these industries will be excluded from consideration here.

### 3.2.2 Asbestos NESHAP Cost Analysis

EPA's economic analysis in the Comprehensive Study divides the affected industries into two major categories: milling and manufacturing.<sup>16</sup> The control requirements and compliance costs for the two categories are sufficiently different to warrant separation here also. Several general observations regarding the economic analysis presented by EPA can be made about both categories.

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<sup>16</sup>Research Triangle Institute, Comprehensive Study..., p. 2-11.

A baseline of behavior in the absence of the promulgated standards is not explicitly presented, although it appears to be estimated current practices. Current practices may not accurately reflect what would have occurred without the standard; as is evidenced by the fact that some, but not all, establishments had adopted technology that placed them close to compliance before the standards were promulgated. It is possible that additional establishments would also have reduced emissions over time without the standards. The extent to which this emission reduction would have occurred is not known, however.

Because of the paucity of information, the accuracy of the cost estimates remains indeterminate. Some retrospective cost data are available and are utilized. The costs used here may include the cost of equipment that could also be used to comply with OSHA regulations promulgated subsequent to the NESHAP (e.g., hoods, vents, ductwork). Because we have not allocated these costs among the two regulations, the cost estimates here are the upper bounds for the cost of the NESHAP regulation. The remainder of this section discusses the compliance cost estimates for the milling and manufacturing industries.

#### The Asbestos Milling Industry

Background. In 1970 there were nine operating asbestos mines and mills in the U.S., five large and four small. Each mill was associated with an asbestos mine and was located at or near the mine site. Exhibit 3-1, showing the compliance costs for the mills, was presented in the Comprehensive Study. A detailed description of the origin of the cost figures is not presented although it was stated that each of the nine plants was examined to determine the equipment required to attain compliance. The costs could have been estimated accurately because the requisite control technology was well-known and proven at the time. However, the assumed life of the equipment, the method of financing, and the consideration of tax effects were not explicitly described. Because social costs are not mentioned in the report, we assumed that the cost estimates accurately reflect private, pre-tax costs.

The report also states that there is a wide variation in compliance costs among plants; from zero to \$5.96 per ton of asbestos. This variation is important because rather than increase its capacity by five percent per year as was anticipated in the Comprehensive Study, the total capacity of the U.S. asbestos milling industry has decreased substantially due to mill closings. The wide variance in the compliance costs among the mills means that estimates of actual total costs are sensitive to assumptions regarding the distribution of compliance costs among mills that closed and those that remained open. Compliance costs for the mills that remained open cannot be estimated solely from the information in EPA's 1972 report. However, information in The Cost of Clean Air<sup>17</sup> (EPA, 1974) and Asbestos<sup>18</sup> (Bureau of Mines, 1980) can be used to calculate ranges for costs imposed by the standards.

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<sup>17</sup>EPA, The Cost of Clean Air (Washington, D.C.: April 1974 [EPA 230/3-74-003]).

<sup>18</sup>Bureau of Mines, Asbestos, A Chapter from Mineral Facts and Problems, 1980 Edition (Washington, D.C.: 1980 [Bulletin 671]).

## EXHIBIT 3-1

EMISSIONS AND NESHAP CONTROL COSTS FOR THE ASBESTOS MILLING INDUSTRY  
(for plants existing in 1970; 1970 dollars)

| Plant Size/<br>Number of Plants |   | Total Emissions          |                                  | Control Costs      |                         | Annual Cost<br>Per Ton of<br>Capacity<br>(\$ per ton) |
|---------------------------------|---|--------------------------|----------------------------------|--------------------|-------------------------|-------------------------------------------------------|
|                                 |   | 1970<br>Actual<br>(tons) | If Fully<br>Controlled<br>(tons) | Investment<br>(\$) | Annual-<br>ized<br>(\$) |                                                       |
| Large                           | 5 | 3,750                    | 150                              | 333,480            | 124,189                 | 0.44                                                  |
| Small                           | 4 | 110                      | 4                                | 8,340              | 3,579                   | 1.38                                                  |
| Total                           | 9 | 3,860                    | 154                              | 341,820            | 128,189                 | 0.78                                                  |
| Average                         |   | 430                      | 17                               | 37,980             | 14,243                  | 0.78                                                  |

a/ Annualized costs include operation and maintenance costs and a cost of capital reflecting the investment required. Assumptions regarding capital costs were not stated explicitly.

Source: Research Triangle Institute, Comprehensive Study of Specified Air Pollution Sources to Assess the Economic Impact of Air Quality Standards: Asbestos, Beryllium, Mercury (Research Triangle Park, N.C.: August 1972 [NTIS PB-222 858]), p. 2-18.



Baseline. Between 1973, when the standards were promulgated, and 1975, three small mills and one large mill discontinued their operations.<sup>19</sup> It is believed that these mills did not attain compliance before closing and it is not known to what extent the standards contributed to their discontinuing operation. The U.S. recession during 1974-75, other regulatory requirements, and the recent development of substitutes for asbestos may have been factors contributing to the mill closings. As shown in Exhibit 3-2, the real average price of asbestos slumped badly during the recession as did U.S. production. Although both the price and world production rebounded sharply in 1976, U.S. production rebounded for the year and then continued to decline. The increase in world production shown in Exhibit 3-2 is misleading because it is primarily accounted for by increased domestic production and consumption in the Soviet Union. The demand for asbestos produced in the West has continued to be slack.

It is very unlikely that the EPA regulations were sufficiently costly to cause the mills to close. Of the three small mills that closed, two are believed to have been only marginally profitable operations, and the third produced only anthophyllite asbestos, a type for which there is little or no current demand.<sup>20</sup> The large mill that closed was owned by Coalinga Asbestos Co., a division of Johns-Manville Corporation.<sup>21</sup> Johns-Manville is currently the largest producer of asbestos in Canada and it is not known why it closed its U.S. operation. In the absence of further information regarding these mills and mines, we assume that these four mills:

- would have closed had the regulations not been promulgated;
- incurred no capital or operating costs due to the NESHA regulations; and
- continued to emit asbestos into the atmosphere at the pre-regulation rate until their closings.

Therefore, the asbestos NESHA generated no costs (or benefits) in relation to these four establishments.

The results of this analysis are not sensitive to these baseline assumptions regarding the small mills. As shown in Exhibit 3-1, all four small mills were predicted to account for under three percent of total

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<sup>19</sup>National Institutes of Health, DHEW, Asbestos: An Information Resource (Washington, D.C.: May 1978 [(NIH) 79-1681]), p. 12.

<sup>20</sup>Bureau of Mines, Asbestos in 1980, Mineral Industry Survey (Washington, D.C.: May 15, 1981), p. 3. Also, personal communication with Mr. R.A. Clifford, U.S. Bureau of Mines, June 19, 1981.

<sup>21</sup>National Institutes of Health, op. cit., p. 12. The Coalinga Mine produced only short-fiber asbestos which is not as valuable as the long-fiber asbestos produced in Canada.

## EXHIBIT 3-2

ASBESTOS PRICE AND PRODUCTION DATA  
1970-1980

|                                             | 1970   | 1971   | 1972   | 1973   | 1974   | 1975   | 1976    | 1977    | 1978    | 1979    | 1980    |
|---------------------------------------------|--------|--------|--------|--------|--------|--------|---------|---------|---------|---------|---------|
| Average price per metric ton (1978 dollars) | 212.14 | 205.16 | 195.48 | 193.62 | 176.64 | 190.02 | 257.34  | 293.92  | 272.69  | 242.15  | N.A. a/ |
| U.S. Production (1,000 metric tons)         | 113    | 119    | 120    | 136    | 103    | 89     | 105     | 92      | 93      | 93      | 80      |
| Total World Production (1,000 metric tons)  | 3444   | 3581   | 2794   | 4171   | 4115   | 4139   | 4767 b/ | 4693 b/ | 4692 b/ | 4890 c/ | 4820 d/ |

a/ not available  
b/ revised  
c/ preliminary  
d/ estimate

Source: Bureau of Mines, Asbestos, A Chapter from Mineral Facts and Problems, 1980 Edition (Washington, D.C.: 1980 (Bulletin 671)), pp. 9, 11.

Bureau of Mines, Asbestos in 1980, Mineral Industry Surveys (Washington, D.C.: May 15, 1981), p. 2.

emissions, total emissions reductions, and total costs. The results may be sensitive to assumptions regarding the closure of the large mill because it represented a significant portion of total U.S. production capacity. The assumptions listed above shall hold for the purposes of this and the next section on effectiveness.

Five mills, one small and four large, remained in operation following the promulgation of the asbestos NESHAP. All five attained compliance and each potentially incurred costs. However, one of the four large mills in operation did not report any production in 1980, and is now apparently closed.<sup>22</sup> Its reason for closing is not known, however, it is likely that the asbestos in that particular location may no longer be economical to recover in today's slack market. If the real price of asbestos increases, these reserves may again become recoverable and the mill may resume operation. However, U.S. production consists primarily of short, low-grade fibers, the price of which is dictated by the large Canadian producers. If and when the mill will resume production can not be predicted, and it is not expected in the near future.

Four mills, one small and three large, remain in operation today. One of the three large mills has always used a proprietary wet processing method whose emissions of asbestos to the atmosphere are very small (for purposes of this analysis we assume these emissions to be zero). This establishment incurred no costs to attain compliance with the asbestos NESHAP. Compliance costs are therefore limited to the two large mills currently in operation, the small mill currently in operation, and the large mill that presumably attained compliance but closed in 1980. Exhibit 3-3 summarizes the data on the number of mills in operation during the 1970s.

Compliance Costs. The baghouse/fabric filter technology described in the Comprehensive Study is assumed to be the emission control technology required to meet the standards. The regulations allow the firms to select the control methods they believe to be best. However, the other options are generally less effective and more costly. Therefore, the fact that the promulgated regulations provide more flexibility in the choice of control equipment than does the Comprehensive Study probably does not affect the accuracy of the cost estimates made by EPA.

Compliance costs for the baghouse/fabric filter technology are a function of both mill capacity and actual production. The capital investment required for the new equipment will vary with the size of the mill. The operation, maintenance (including changing the filters), and equipment life will vary with actual production.

Exhibit 3-1 shows the EPA estimates of compliance costs for large and small mills as a function of capacity only. A cost of \$0.44 per ton of capacity is reported for large mills. This cost figure is suspect for several reasons. For example, it appears as though the capacity of the wet process mill (that incurred no compliance costs) was included in the computation. Also, given the estimated \$124,000 annualized control cost for the large mills, a total capacity of over 280,000 tons per year is implied. This is

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<sup>22</sup>Bureau of Mines, Asbestos in 1980..., op. cit., p. 1.

## EXHIBIT 3-3

## SUMMARY OF ASBESTOS MILLS IN OPERATION DURING THE 1970s

| Mill Size | 1970               | 1976               | 1980               |
|-----------|--------------------|--------------------|--------------------|
| Large     | <sup>a/</sup><br>5 | <sup>a/</sup><br>4 | <sup>a/</sup><br>3 |
| Small     | 4                  | 1                  | 1                  |
| Total     | 9                  | 5                  | 4                  |

<sup>a/</sup> One large mill uses a wet processing method that does not emit asbestos to the atmosphere.

greater than the total capacity of the industry reported as 163,000 tons per year in the same report.<sup>23</sup> Therefore, we did not use the annualized control cost estimate of \$0.44 per ton for large mills to extrapolate costs to the current capacity of the industry and is not used here.

Annualized control cost figures ranging from \$1.30 to \$4.30 per ton of "production capacity" for large mills are reported in The Cost of Clean Air.<sup>24</sup> These data, presented in Exhibit 3-4, do not explicitly differentiate between tons of capacity and tons of actual production, and the sources of the data are not identified. The report uses the phrase "mill size," and reports that the estimates are based on inspections of the mill locations. Assuming these estimates are approximately correct, the compliance costs for each of the four mills identified above as having incurred costs can be estimated by matching the actual mills to the appropriate rows in Exhibit 3-4. Difficulties arise, however, because the "capacities" or "sizes" of the mills of interest do not exactly match the sizes reported in Exhibit 3-4.

In 1976 the three large mills then in operation had annual capacities previously identified as being between 30 and 40 thousand tons of asbestos each.<sup>25</sup>

<sup>23</sup>Research Triangle Institute, Comprehensive Study..., op. cit., p. 2-19.

<sup>24</sup> EPA, The Cost of Clean Air, op. cit., p. 12.

<sup>25</sup> National Institutes of Health, op. cit., p. 12.



## EXHIBIT 3-4

NESHAP CONTROL COSTS FOR ASBESTOS MILLS OF VARIOUS SIZES  
ESTIMATED IN THE COST OF CLEAN AIR a/

| Size<br>(1000 tons/yr)<br>(1) | Investment Costs<br>(1000 dollars)<br>(2) | Annualized Cost<br>(1000 dollars)<br>(3) | Annualized <u>b/</u><br>Cost per ton<br>(3) <sup>+</sup> (1)<br>(4) |
|-------------------------------|-------------------------------------------|------------------------------------------|---------------------------------------------------------------------|
| 0.02                          | 0.98                                      | 0.43                                     | 21.5                                                                |
| 0.07                          | 0.66                                      | 0.29                                     | 4.1                                                                 |
| 0.19                          | 3.82                                      | 1.67                                     | 8.8                                                                 |
| 0.76                          | 2.55                                      | 1.13                                     | 1.5                                                                 |
| 2.29                          | 18.70                                     | 7.20                                     | 3.1                                                                 |
| 6.20                          | 65.00                                     | 26.60                                    | 4.3                                                                 |
| 22.90                         | 73.60                                     | 29.10                                    | 1.3                                                                 |
| 61.90                         | <u>254.80</u>                             | <u>106.60</u>                            | 1.7                                                                 |
| TOTAL                         | 420.11                                    | 173.15                                   |                                                                     |

a/ 1973 dollars.

b/ A range of +25% was reported along with these expected values listed here.

Source: EPA, The Cost of Clean Air (Washington, D.C.: April 1974 [EPA 230/3-74-003]), p. IV-174

However, only one mill is reported to have a "size" greater than 22.9 thousand tons per year. Because of the inconsistencies in the available data, annualized costs were approximated as follows:

- Assume the three largest mills listed in Exhibit 3-4 are the ones that remained in operation beyond 1976 and attained compliance.
- Assume the smallest of those three large mills closed in 1980 and is not expected to reopen in the foreseeable future. Assume also that the equipment required for this firm to attain compliance has not been resold and that the firm incurred the full capital cost of the equipment.
- Assume the compliance cost for the small mill that remained in operation equals the average of the compliance costs for the four small units.

The annualized cost of compliance estimated with the above assumptions is shown in Exhibit 3-5. In 1980 large mill number 3 ceased operation and no longer incurs operation and maintenance costs. However, the annualized costs include capital investment costs spread over the (assumed) ten year life of the equipment. (Ten years was chosen because that is the life of similar equipment reported in the section on asbestos manufacturing.) At a ten percent interest rate the \$65 thousand capital cost equals \$10 thousand per year for ten years, which is shown in the exhibit.<sup>26</sup> Once the mill ceases to operate, it does not actually incur these costs. The firm will write off the current book value of the equipment as a loss net of any salvage value obtainable. This cost could therefore be shown as a lump sum in 1980. To maintain consistency in the presentation of annualized costs, the capital costs are shown over the full life of the equipment, even though the firm has gone out of business. Therefore, Exhibit 3-5 shows mill number 3 with \$10 thousand annualized costs from 1980-1983, and zero costs thereafter. (For simplicity, potential salvage value is assumed to be very small or negligible.)

The total annualized cost of compliance for asbestos mills was therefore approximately \$276 thousand per year during the second half of the 1970s and, due to an additional mill closing, will drop to about \$230 thousand per year. The accuracy of these figures is no better than  $\pm 25$  percent because the cost data in The Cost of Clean Air, on which these estimates are based, were reported as  $\pm 25$  percent.<sup>27</sup> When also expressed in 1980 dollars, the

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<sup>26</sup> An interest rate of ten percent was chosen to represent the likely cost of capital at the time. At an interest rate of twenty percent the annualized cost is \$13 thousand, and at five percent it is \$8 thousand.

<sup>27</sup> EPA, The Cost of Clean Air, op. cit., p. IV-174

## EXHIBIT 3-5

ESTIMATED ANNUALIZED COST OF COMPLIANCE FOR ASBESTOS MILLS  
 THAT ATTAINED COMPLIANCE WITH THE ASBESTOS NESHAP a/  
 (thousands of dollars)

| Year   | Small Mill <u>b/</u> | Large Mills |      |                 |                 | Total | Total<br>(1980 \$) |
|--------|----------------------|-------------|------|-----------------|-----------------|-------|--------------------|
|        |                      | #1          | #2   | <u>c/</u><br>#3 | <u>d/</u><br>#4 |       |                    |
| 1974   | 0.88                 | 106.6       | 29.1 | 26.6            | 0               | 163.2 | 276                |
| 1975   | 0.88                 | 106.6       | 29.1 | 26.6            | 0               | 163.2 | 276                |
| 1976   | 0.88                 | 106.6       | 29.1 | 26.6            | 0               | 163.2 | 276                |
| 1977   | 0.88                 | 106.6       | 29.1 | 26.6            | 0               | 163.2 | 276                |
| 1978   | 0.88                 | 106.6       | 29.1 | 26.6            | 0               | 163.2 | 276                |
| 1979   | 0.88                 | 106.6       | 29.1 | 26.6            | 0               | 163.2 | 276                |
| 1980   | 0.88                 | 106.6       | 29.1 | 10.0            | 0               | 146.6 | 248                |
| 1981   | 0.88                 | 106.6       | 29.1 | 10.0            | 0               | 146.6 | 248                |
| 1982   | 0.88                 | 106.6       | 29.1 | 10.0            | 0               | 146.6 | 248                |
| 1983   | 0.88                 | 106.6       | 29.1 | 10.0            | 0               | 146.6 | 248                |
| 1984 + | 0.88                 | 106.6       | 29.1 | 0               | 0               | 136.6 | 231                |

a/ 1973 dollars unless noted otherwise.

b/ Average of costs for four small mills.

c/ Discontinued operations in 1980.

d/ Uses a wet milling process and does not emit asbestos to the atmosphere.

Comprehensive Study compliance cost predictions for all nine mills falls within this wide range. These are the best available estimates for the social cost of compliance to the NESHAP for asbestos mills. Costs will be offset to some extent by the value of recovered asbestos fibers. This will be discussed more fully in Section 3.2.3, Asbestos NESHAP Effectiveness Analysis, in which the quantity of asbestos emissions prevented by the standard is estimated.

### The Asbestos Manufacturing Industry

Background. The asbestos manufacturing industry includes Standard Industrial Classification (SIC) Code 3292, Asbestos Products, and portions of other four-digit SIC categories including asbestos paper (Building paper and board mills, SIC 2661) and asbestos gaskets and some insulation (Gaskets, packing and sealing devices, SIC 3293). Exhibit 3-6 displays the annual consumption of asbestos in the U.S. and the percentage accounted for by SIC 3292. SIC 3292 reportedly accounts for over 90 percent of the annual use of asbestos in manufacturing in the United States. As mentioned previously, there is actually considerable uncertainty surrounding the distribution of asbestos among various uses in the U.S. Domestic production of asbestos (discussed in the previous section) accounts for less than ten percent of the total asbestos used in manufacturing in the U.S; most asbestos is imported from Canada (between 85 and 90 percent).

Exhibit 3-7 shows EPA's Comprehensive Study estimates of NESHAP compliance costs for the asbestos manufacturing industry. EPA divided the industry into five major parts which, according to EPA estimates, account for over 90 percent of total asbestos consumption in manufacturing. Bureau of Mines estimates, shown in parentheses in Exhibit 3-7, show that the products examined by EPA account for approximately two-thirds of the total domestic asbestos consumption. The discrepancy is probably caused by EPA using a broad interpretation of "asbestos cement products" to include miscellaneous items, whereas the Bureau of Mines figures include only asbestos cement pipe and sheet. The EPA estimate of 50 percent of domestic asbestos usage going into asbestos cement products is likely to be a better approximation of the total asbestos used at cement plants than the Bureau of Mines estimate. Therefore, because emission control costs are plant specific and not product specific, EPA's estimated coverage of over 90 percent of total domestic asbestos consumption is believed to be fairly accurate. The annualized compliance cost is estimated to be \$3.2 million (1980 dollars).

Baseline. The basis for EPA's compliance cost estimates is not explicitly stated. Plant inspections do not appear to have been made and the data sources are not identified. The baseline for control technology adopted in the absence of the standard was assumed in the Study to be "95 percent of potential emissions controlled" for the categories: asbestos cement; floor tile; friction products; and paper products. The baseline for asbestos textile products is identified as 85 percent of potential emissions controlled. Apparently, therefore, Exhibit 3-7 represents the incremental costs of controlling the last five to fifteen percent of "potential emissions." The basis for these baseline assumptions (e.g., occupational safety requirements or economical product recovery), is not provided.



## EXHIBIT 3-6

U.S. CONSUMPTION OF ASBESTOS AND THE PERCENTAGE  
ACCOUNTED FOR BY SIC 3292  
(thousands of metric tons)

| <u>Year</u> | <u>Asbestos Used<br/>(thousands of<br/>metric tons)</u> | <u>Percent<br/>Accounted<br/>for by SIC 3292 a/</u> |
|-------------|---------------------------------------------------------|-----------------------------------------------------|
| 1970        | 666                                                     | 95                                                  |
| 1971        | 689                                                     | 95                                                  |
| 1972        | 734                                                     | 95                                                  |
| 1973        | 795                                                     | 95                                                  |
| 1974        | 768                                                     | 89                                                  |
| 1975        | 552                                                     | 86                                                  |
| 1976        | 660                                                     | 93                                                  |
| 1977        | 609                                                     | 92                                                  |
| 1978        | 619                                                     | 93                                                  |
| 1979        | 561 <u>b/</u>                                           | 96                                                  |
| 1980        | 359 <u>b/</u>                                           | 96                                                  |

a/ Estimated by subtracting asbestos consumption for paper products, packing, and gaskets from total U.S. consumption, and dividing the remainder by the total.

b/ Preliminary.

Sources: Bureau of Mines, Asbestos, A Chapter from Mineral Facts and Problems, 1980 Edition (Washington, D.C.: 1980 [Bulletin 671]), p. 9.

Bureau of Mines, Asbestos in 1980, Mineral Industry Surveys (Washington, D.C.: May 15, 1981), p. 3.

Office of Management and Budget, Standard Industrial Classification Manual, 1972 (Washington, D.C.: 1972 [GPO Stock Number 4101-0066]), p. 143.

## EXHIBIT 3-7

ASBESTOS MANUFACTURING INDUSTRY NESHA  
COMPLIANCE COSTS  
(1970 dollars)

| <u>Production Group</u> | <u>No. of Plants</u> | <u>Percent of Total Asbestos Consumption</u> | <u>Value of Product (Millions of \$)</u> | <u>Investment (1000\$)</u> | <u>Annualized Cost (1000\$)</u> | <u>Annualized Cost to Product Value Ratio (%)</u> |
|-------------------------|----------------------|----------------------------------------------|------------------------------------------|----------------------------|---------------------------------|---------------------------------------------------|
| Asbestos Cement         | 48                   | 50 (30) <sup>a/</sup>                        | \$142.7                                  | 2,400                      | 720                             | 0.5                                               |
| Floor tile              | 18                   | 24 (22) <sup>a/</sup>                        | 37.2                                     | 216                        | 64.8                            | 0.2                                               |
| Friction material       | 30                   | 13 (10) <sup>a/</sup>                        | 202.8                                    | 720                        | 216.0                           | 0.1                                               |
| Asbestos paper          | 29                   | 4 (3) <sup>a/</sup>                          | 5.6                                      | 348                        | 104.4                           | 1.9                                               |
| Asbestos textiles       | <u>34</u>            | <u>2 (2) <sup>a/</sup></u>                   | <u>9.9</u>                               | <u>1,700</u>               | <u>510.0</u>                    | <u>5.2</u>                                        |
| Total                   | 159                  | 93 (67) <sup>a/</sup>                        | \$398.2                                  | \$5,384                    | \$1,615.2                       | 0.4                                               |
| Total (1980 dollars)    | --                   | --                                           | 780                                      | 10,540                     | 3,160                           | 0.4                                               |

<sup>a/</sup> Average percentage for 1969 through 1980. Estimated from: Bureau of Mines, Asbestos, A Chapter from Mineral Facts and Problems, 1980 Edition (Washington, D.C.: 1980 [Bulletin 671]), p. 9.

Source: Research Triangle Institute, Comprehensive Study of Specified Air Pollution Sources to Assess the Economic Impact of Air Quality Standards: Asbestos, Beryllium, Mercury (Research Triangle Park, N.C.: 1972 [NTIS PB-222 858]), p. 2-34.

Compliance Costs. Exhibits 3-8 and 3-9 present alternative cost estimates. Exhibit 3-8, taken from The Cost of Clean Air (EPA, 1974), includes the additional category Miscellaneous Classes that the Comprehensive Study did not include. The cost data from The Cost of Clean Air are plant specific and are separated for "large" and "small" plants in each of the different product categories. To estimate the total cost of compliance, the number of large and small plants were estimated and multiplied by the estimates of cost per plant. Aggregate employment and value-added data for SIC 3292 were used to estimate the number of plants of the two sizes. Plants with under 100 employees were found to account for only seven percent of the total value-added for the industry,<sup>28</sup> even though they make up 57 percent of the plant locations.<sup>29</sup> The small number of plants with 100 to 249 employees account for 23 percent of value added and are considered "large" for the purposes of this report along with locations having greater than 249 employees. Textiles, comprising a large portion of control costs, were investigated separately. Based on similar information it was found that 40 percent of the locations can be considered "small" and 60 percent "large."<sup>30</sup> Therefore, as shown in Exhibit 3-8, we estimate annualized compliance costs for the asbestos NESHAP to equal \$2.7 million (1980 dollars). The accuracy of this estimate is at best  $\pm 25$  percent.<sup>31</sup>

The \$2.7 million compliance cost estimate derived from data The Cost of Clean Air is similar to the Comprehensive Study estimate of \$3.2 million. The independence of the estimates is uncertain, however, because it is likely that the 1974 report was based, in part, on data collected for the 1972 report. Therefore, although the compliance cost estimates come from two separate documents, they should not be viewed as corroborating statistics.

Exhibit 3-9 presents particulate air pollution control expenditures reported by establishments in the Asbestos Products industry, SIC 3292. The cost figures, broken down into capital expenditures and operation and maintenance costs, are reported each year to the Bureau of the Census as part of a program to obtain management's best informed judgment of the actual costs of air, water, and solid waste pollution control.<sup>32</sup>

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<sup>28</sup>Arthur D. Little, Economic Analysis of Effluent Guidelines for the Asbestos Industry (Washington, D.C.: December 1974 [NTIS PB-238 268]), p. 21.

<sup>29</sup>Department of Commerce, County Business Patterns (Washington, D.C.).

<sup>30</sup>Arthur D. Little, Economic Analysis of Effluent Guidelines: The Textiles, Friction and Sealing Materials Segment of the Asbestos Manufacturing Industry (Washington, D.C.: July 1975 [NTIS PB-250 683]), pp. 8-9.

<sup>31</sup>The cost estimates in The Cost of Clean Air were reported as  $\pm 25$  percent.

<sup>32</sup>U.S. Bureau of the Census, Pollution Abatement Costs and Expenditures, (Washington, D.C.: 1975 [MA-200(75)-1]), Appendix A.

EXHIBIT 3-8  
ESTIMATE OF NESHA<sup>a</sup>P COMPLIANCE COSTS FOR SELECTED MODEL PLANTS AND THE  
ENTIRE ASBESTOS MANUFACTURING INDUSTRY a/

| Product Group     | Plant Size | Investment Cost per Plant (1000\$) | Annualized Cost per Plant (1000\$) | Number of Plants in Product Group | Percent of "Large" Plants in Product Group <u>c/</u> | Annualized Cost for Product Group (1000\$) |
|-------------------|------------|------------------------------------|------------------------------------|-----------------------------------|------------------------------------------------------|--------------------------------------------|
| Asbestos Cement   | LARGE      | 34                                 | 12                                 | 48                                | 43%                                                  | 428                                        |
|                   | SMALL      | 20                                 | 6.6                                |                                   |                                                      |                                            |
| Floor Tile        | LARGE      | 9.8                                | 3.3                                | 18                                | 43%                                                  | 44                                         |
|                   | SMALL      | 5.6                                | 1.8                                |                                   |                                                      |                                            |
| Friction Material | LARGE      | 21.4                               | 7.1                                | 30                                | 43%                                                  | 164                                        |
|                   | SMALL      | 13.1                               | 4.3                                |                                   |                                                      |                                            |
| Paper             | LARGE      | 24.9                               | 8.3                                | 29                                | 43%                                                  | 186                                        |
|                   | SMALL      | 14.9                               | 5.0                                |                                   |                                                      |                                            |
| Textiles          | LARGE      | 61.6                               | 20.2                               | 34                                | 60%                                                  | 577                                        |
|                   | SMALL      | 36.2                               | 12.1                               |                                   |                                                      |                                            |
| Miscellaneous     | LARGE      | 1.4                                | 0.5                                | (b)                               | (b)                                                  | 201                                        |
|                   | SMALL      | 0.9                                | 0.3                                |                                   |                                                      |                                            |
| Total (1973\$)    |            |                                    |                                    |                                   |                                                      | \$1,600                                    |
| Total (1980\$)    |            |                                    |                                    |                                   |                                                      | \$2,700                                    |

a/1973 dollars unless noted otherwise. All estimates are plus-or-minus 25 percent.

b/"Hundreds" of plants are reported in The Cost of Clean Air, with over 300 in manufacturing packing and gaskets. A total of 500 plants are assumed, 250 large and 250 small.

c/See text for derivation.

Source: EPA, The Cost of Clean Air (Washington, D.C.: April 1974 [EPA 230/3-74-003]), pp. IV-171, IV-174.



## EXHIBIT 3-9

INDUSTRY CAPITAL AND OPERATING COSTS FOR  
 REDUCING PARTICULATE AIR EMISSIONS:  
 1973-1977, SIC 3292 a/  
 (millions of dollars)

| Year | Current Dollars      |                 | 1980 Dollars         |                 | Total |
|------|----------------------|-----------------|----------------------|-----------------|-------|
|      | Capital Expenditures | Operating Costs | Capital Expenditures | Operating Costs |       |
| 1973 | 2.8                  | 2.9             | 4.8                  | 4.9             | 9.7   |
| 1974 | 4.5                  | 3.0             | 7.0                  | 4.6             | 11.6  |
| 1975 | 5.5                  | 3.8             | 7.8                  | 5.4             | 13.2  |
| 1976 | 3.9                  | 4.8             | 5.1                  | 6.5             | 11.6  |
| 1977 | 4.0                  | 5.1             | 5.1                  | 6.5             | 11.6  |

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a/ Obtained by the Bureau of the Census by sending written questionnaires to all establishments in SIC 3292. Does not include Asbestos Paper products (part of SIC 2661) or Packing and Gaskets (part of SIC 3293). Costs shown are not all attributable to the NESHAP regulation.

Source: U.S. Bureau of the Census, Pollution Abatement Costs and Expenditures (Washington, D.C.: 1973-1977 [MA-200(73-77)1]).

The costs reported to the Bureau of the Census in this category are not the result of other EPA regulations because the 1973 asbestos NESHA<sup>1</sup> is the particulate air pollution control requirement for SIC 3292. However, these estimates may include costs that are more appropriately attributable to the OSHA asbestos requirements. Also, the costs reported by industry are total costs of particulate emissions controls, not the incremental costs imposed by the NESHA<sup>1</sup>. According to EPA, a significant portion of particulate air emissions was controlled before the standards were promulgated. Therefore, most of the costs reported by industry are actually costs they would have incurred anyway (see discussion of baseline).

Assuming the appropriate baseline of annual expenditures is 90 percent of the reported 1973 costs, i.e., \$8.7 million per year, we estimate the average incremental cost per year due to the NESHA<sup>1</sup> to be \$3.3 million for 1974 to 1977 and \$2.8 million for 1973 to 1977 (1980 dollars). These results are similar to the EPA estimates described above, but control costs for asbestos paper producers are not included. The conclusions drawn from the Bureau of Census data are very sensitive to assumptions regarding baseline expenditures. Exhibit 3-10 displays a graph of how estimates of annual compliance costs for SIC 3292 vary with the assumption regarding the appropriate percentage of 1973 expenditures that should be considered baseline annual costs. Additional pre-1973 information is required to assess more accurately the level of baseline expenditures in these Census figures. These data are not available because the Bureau of the Census first collected this information in 1973. Therefore, from these data the average annualized compliance cost can be bounded at \$2.3 million and \$12 million, but given baseline considerations can be expected to be between approximately \$2.8 million and \$3.8 million.<sup>22</sup>

All the compliance cost estimates described above assume there are no significant balance of trade, employment, or price effects. In light of the available information, this assumption appears reasonable.

A further adjustment to the EPA cost estimates may be required because they implicitly assumed that production levels would remain at their pre-1973 rate. As mentioned above, the demand for asbestos has slackened considerably since that time and demand for asbestos products has decreased also. Exhibit 3-11 displays several measures of the economic activity in the asbestos industry. Insofar as compliance costs vary with actual production levels, the EPA estimates of compliance costs may be too high. The Bureau of Mines predicts annual domestic consumption of asbestos to remain stable around 620 thousand metric tons for the next twenty years.<sup>24</sup> This is approximately 16 percent less than the consumption upon which the EPA estimates are based. If

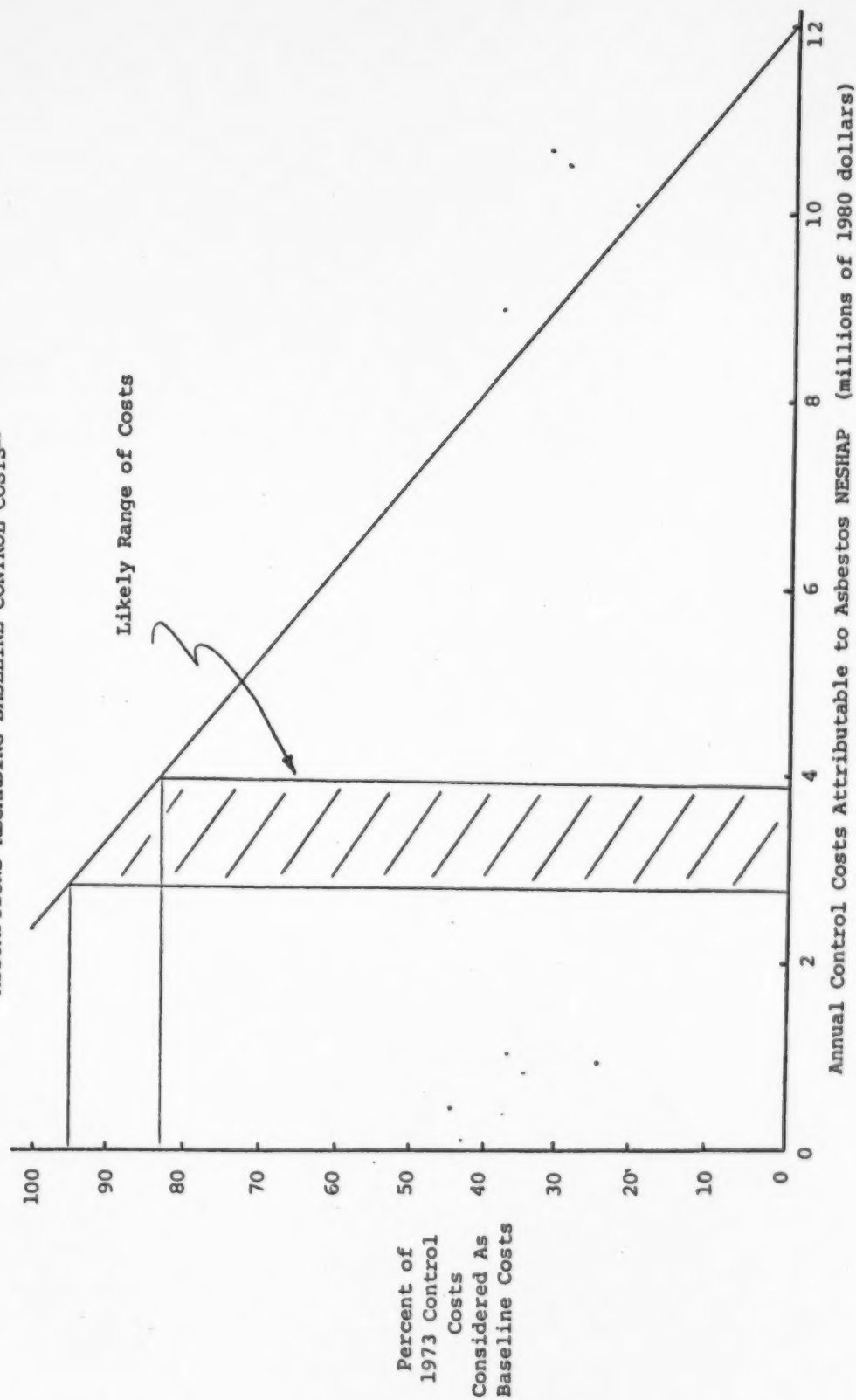
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<sup>22</sup>A high baseline level of expenditures is expected because as described below in the Effectiveness Analysis, a large portion of emissions was controlled prior to the promulgation of the standard.

<sup>24</sup>Bureau of Mines, Asbestos, A chapter ..., op. cit., p. 14.

# EXHIBIT 3-10

SENSITIVITY OF ANNUAL CONTROL COST ESTIMATES FOR SIC 3292 TO ASSUMPTIONS REGARDING BASELINE CONTROL COSTS<sup>a/</sup>



<sup>a/</sup> See text for derivation.

EXHIBIT 3-11  
MEASURES OF ECONOMIC ACTIVITY IN ASBESTOS MANUFACTURING  
SHOWING DECLINE DURING THE 1970s

| <u>Year</u> | <u>Quantity of<br/>Asbestos Consumed in<br/>U.S. <u>a/</u> (thousands<br/>of metric tons)</u> | <u>Value of Ship-<br/>ments from Estab-<br/>lishments in SIC<br/>3292 <u>b/</u> (millions<br/>of 1978 dollars)</u> | <u>Value of Shipments<br/>in SIC 3292 Product<br/>Class <u>c/</u> (millions<br/>of 1978 dollars)</u> |
|-------------|-----------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|
| 1972        | 734                                                                                           | 1,161                                                                                                              | 1,129                                                                                                |
| 1973        | 795                                                                                           | 1,341                                                                                                              | 1,148                                                                                                |
| 1974        | 768                                                                                           | 1,324                                                                                                              | 1,195                                                                                                |
| 1975        | 552                                                                                           | 1,064                                                                                                              | 985                                                                                                  |
| 1976        | 660                                                                                           | 1,025                                                                                                              | 1,075                                                                                                |
| 1977        | 609                                                                                           | 803                                                                                                                | (d)                                                                                                  |
| 1978        | 619                                                                                           | 843                                                                                                                | (d)                                                                                                  |
| 1979        | 561                                                                                           | (d)                                                                                                                | (d)                                                                                                  |

a/ Bureau of Mines, Asbestos, A Chapter from Mineral Facts and Problems, 1980 Edition (Washington, D.C.: 1980 [Bulletin 671]), p. 9.

b/ Department of Commerce, 1981 U.S. Industrial Outlook (Washington, D.C.: 1980), p. 547.

c/ Department of Commerce, Annual Survey of Manufactures 1975-1976 (Washington, D.C.: May 1979), p. 2-17.

d/ Not Available.



operation and maintenance costs vary directly with the quantity of asbestos used (which is probably an overestimate of the sensitivity of these costs), then total annualized compliance costs may be overestimated by approximately five percent because one-third of the Comprehensive Study estimate of annualized cost is specifically attributed to operation and maintenance of equipment. This potential error is too small to warrant an adjustment of the estimates presented here which are already uncertain.

Given the considerations described above, we estimate the NESHAP compliance cost for the asbestos manufacturing industry to be \$3.3 million annually, plus or minus \$0.8 million. This is representative of the Comprehensive Study estimate, and the estimates we derived from data in The Cost of Clean Air and the Bureau of Census reports.

If improved NESHAP compliance cost estimates were desired, primary data collection would be required. The individual mines, mills, and manufacturing locations currently operating could be contacted to obtain estimates of incremental costs imposed by the regulation. Information on actual equipment purchases and maintenance costs could be examined. Additionally, information on asbestos product fabrication, asbestos waste disposal, and building demolition and renovation would be required. The extent of expected industry cooperation in a study of this sort is often uncertain, however, valuable information may be obtainable.

### 3.2.3 Asbestos NESHAP Effectiveness Analysis

The purpose of the asbestos NESHAP is to reduce air emissions of asbestos fibers. Exposures to airborne asbestos have been linked, to various degrees, to:<sup>11</sup>

- Asbestosis in humans, a chronic, progressive pneumoconiosis;
- Restrictive pulmonary dysfunction in humans; and
- Lung cancer, mesothelioma, and other cancers in humans.

The benefits of the regulation will be in the form of reduced morbidity, reductions in premature deaths, and concomitant reduction in medical costs, lost income, pain, and suffering.

Assessing the extent to which mandated reductions in point source asbestos emissions will cause reductions in these adverse health effects requires the specification of a complex model of: emissions; dispersion and

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<sup>11</sup>EPA, Ambient Water Quality Criteria for Asbestos (Washington, D.C.: October 1980 [EPA 440/5-80-022]), pp. 32-69.

presence; exposure; and effect.<sup>36</sup> Each component in the model will have both temporal and spacial parameters affecting its link to the other components and its influence on human health. For several reasons this model can not be sufficiently defined for the approximation of health benefits resulting from the asbestos NESHAP.

The effect that reductions in point source emissions will have on ambient asbestos concentrations cannot be determined. Of the approximate 240,000 metric tons of asbestos known to be discharged annually to the environment, less than two percent is directly discharged to air.<sup>37</sup> The overwhelming majority of asbestos is "disposed" to land, which during transportation and/or disposal may enter the air. The relative contributions of the various asbestos related activities including product use to the ambient concentration of asbestos is not known.<sup>38</sup> Air emissions may account for the largest environmental source of human exposure. The contribution that the activities regulated under the 1973 NESHAP would have made (or currently make) to ambient asbestos levels has not been determined.

Due to measurement difficulties, questions regarding the past and current presence of and exposure to ambient asbestos cannot be answered. Intralaboratory ambient measurement variability has been found to exceed a factor of 10 and the results between laboratories can differ by a factor of 100.<sup>39</sup> Part of the measurement difficulty is being able to identify asbestos in ambient air samples, of which it is only a small portion. A second difficulty is knowing which asbestos fibers to count. Occupational exposures to asbestos are measured by only counting fibers greater than five microns. However, fibers of this length may only account for five percent of total ambient asbestos.<sup>40</sup> The distribution of fiber lengths, which to date is not well characterized, may affect the expected health effects from a given ambient mass concentration of asbestos. Although still uncertain, it is believed that fibers of different lengths may cause different effects in humans.

A significant amount of effort would be required to develop estimates of the health benefits of the asbestos NESHAP. Primary data collection and dispersion modeling would be required to assess the extent to which the

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<sup>36</sup>ICF Incorporated, Feasibility of Measuring and Comparing The Cost-Effectiveness of EPA Regulatory Efforts to Control Toxics-Related Health Risks (Washington, D.C.: March 1981), pp. 2-1 to 2-5.

<sup>37</sup>EPA, Ambient Water Quality..., op. cit., p. A-1.

<sup>38</sup> Ibid, p. C-22.

<sup>39</sup> Ibid, p. C-6; Mr. Gil Wood of OAQPS, EPA, reports that an interim method for ambient sampling and analysis of airborne asbestos has recently been developed. However, a reproducible method for stack samples is not available and dispersion models have not been calibrated for asbestos.

<sup>40</sup> Ibid., p. C-9.

sources controlled by the rule contribute to ambient concentrations of asbestos.<sup>41</sup> Additional air sampling and analysis may be needed to support estimates of exposures. Health benefits from the asbestos NESHAP will not be estimated here because:

- The relationship between point source emissions and ambient concentration is not known;
- There are not sufficient time-series data of ambient air concentrations including both pre- and post- 1973; and
- The effects that exposure levels (in the relevant range) have on people are not well quantified.

Therefore, this assessment of the effectiveness of the asbestos NESHAP will focus on the amount of asbestos air emissions prevented by the regulation.

As in the previous section on costs, the analysis of the effectiveness of the asbestos NESHAP can be divided into two parts: the milling industry and the manufacturing industry. The major data source is EPA's Comprehensive Study for the original rule.<sup>42</sup> The amendments to the rule are not examined nor are the industries excluded from consideration in the Comprehensive Study.

#### The Asbestos Milling Industry

Baseline. Although there were nine operating asbestos mills in the U.S. in 1973 when the NESHAP was promulgated, four closed by 1975. It is believed that these four mills continued to emit asbestos to the atmosphere at the pre-regulation rate until their closings. Therefore, the asbestos NESHAP generated no benefits (or costs) in relation to these four establishments. Of the remaining five, one uses a wet milling process that does not emit asbestos to the atmosphere. Therefore, the benefits of the regulation will be measured as the tons of asbestos emissions prevented at the other four mills.

One small mill and three large mills make up the four mills that actually reduced their asbestos air emission. One of the large mills closed its operations in 1980 (see the previous section on costs for a discussion of the mill closings). Therefore, emission reductions at this mill only occurred from 1974-1979. It is assumed that significant emissions occurred at all the mills in 1973 when equipment was presumably being purchased and installed to attain compliance.

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<sup>41</sup>Some of this may be performed as part of EPA's documentation of its proposed control of Commercial and Industrial Use of Asbestos Fibers (44 FR 60061).

<sup>42</sup>EPA, Comprehensive Study ..., op. cit.

EPA's Comprehensive Study reported that prior to the 1973 regulations, the "overall emissions by the asbestos milling industry ... is 100 pounds per ton of asbestos produced, or a rate of loss of about five percent."<sup>43</sup> The basis for this estimate is not provided, however, it is assumed that a mass balance or other engineering approach was used. For example, the amount of asbestos entering the mill can be determined because the weight and asbestos content of the ore is measurable. The difference between the quantity of asbestos entering the mill and the sum of the asbestos produced and disposed of as solid waste must equal air emissions of asbestos. Using the relationship among these quantities, the quantity of asbestos air emissions that would have occurred in the absence of the NESHAP requirements can be expressed as a function of the actual amount of asbestos produced.

In order for EPA's estimate of a five percent rate of air emissions to be correct for the purpose of estimating emissions prevented by the regulation, the technology used by the industry would have had to have remained constant in the absence of the standard. Although some advances have been made in the automation and computer control of equipment, there has been little change in the basic milling methods and processes.<sup>44</sup> The five percent emission rate would probably be reasonable for baseline emissions of all nine mills. However, the large mill that uses a wet process currently makes up a larger percentage of total production than it did previously. Therefore, the emission rate must be adjusted to reflect the increased percentage of total production accounted for by the process that does not emit asbestos to the atmosphere.

In 1970 the wet process mill accounted for approximately fifteen percent of total production. Therefore, the emission rate for the other plants was greater than five percent of their total production and was actually 5.9 percent (assuming the five percent figure correctly represented emissions from all 9 mills in 1970). Because of the closing of two large and three small mills during the 1970's, the wet process mill currently accounts for approximately thirty percent of total production, making the baseline industry emission rate 4.1 percent for the currently operating mills. A rough approximation of baseline emissions is taken to be five percent of annual domestic production from 1974 to 1979 and 4.1 percent thereafter.

Emission Reduction. Assuming one-hundred percent compliance, EPA's Comprehensive Study predicted a 96 percent reduction in emissions that would have occurred in the absence of the standard. This was based on engineering estimates of the removal efficiency of the technology analyzed in that report. However, the promulgated standards allow the individual mills to adopt whatever technologies they believe to be best. The removal efficiency of the equipment itself may vary. Also the collection efficiency of the system that carries the fibers to the baghouse/fabric filters may vary. The collection efficiency may be below 100 percent, and is often sensitive to equipment maintenance and work practices.

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<sup>43</sup>EPA, Comprehensive Study ..., op. cit., p. 2-17.

<sup>44</sup>Bureau of Mines, Asbestos, A Chapter ..., op. cit., p. 6.



Although the "no visible emissions" requirement that was adopted enables mills to vent asbestos emissions from some processes directly to the atmosphere, EPA has found in recent plant inspections that all processes are vented through the appropriate control devices and that the control equipment is well maintained. Therefore, the total removal efficiency estimate of 96 percent will be used here. This estimate is fairly uncertain, but until additional field testing data are available, it cannot be improved.

To estimate the number of tons of asbestos emissions prevented, an estimate of the amount of total production accounted for by mills in compliance is required. The one large mill and three small mills that did not attain compliance while in operation and subsequently closed in 1975 accounted for approximately twenty percent of production in 1974 and 1975. The NESHAP did not reduce emissions from these mills. The three large mills and one small mill that attained compliance while in operation accounted for approximately 65 percent of total production in 1974 and 1975, 85 percent from 1976 to 1979, and 70 percent thereafter (because one of the large mills closed). The wet process mill, as described above, accounted for approximately 15 percent of total production from 1974 to 1979, and 30 percent thereafter. Exhibit 3-12 summarizes the assumed level of baseline emissions and the amount of asbestos emissions prevented.

The estimated annual average quantity of asbestos emissions prevented by the NESHAP was 3.5 thousand metric tons (+ 25 percent) for the period 1974 through 1980. This is on the low side of the EPA estimates of 3.4 to 4.7 thousand metric tons reported in the Comprehensive Study. The high EPA estimate incorporates expected growth and a high removal efficiency. Because the industry declined, the lower 3.4 figure is more representative of EPA's predicted annual rate of emission reduction.

The future number of tons of asbestos air emissions prevented by the NESHAP depends on how much asbestos is mined and milled in the U.S. As shown in Exhibit 3-12, the Bureau of Mines predicts annual asbestos production to be between 50 and 150 thousand metric tons by the year 2000. Using these two figures as bounds, the average annual quantity of asbestos emissions prevented may range from 2.9 to 4.4 thousand metric tons.

This 2.9 to 4.4 thousand metric tons represents the asbestos removed annually from the air at the mill. A small portion of this quantity can be sold by the mill as low grade asbestos fiber. Although as much as fifty percent of the filter catch was reported as salable in 1972,<sup>45</sup> the usable portion of the incremental catch resulting from the regulations is likely to be significantly lower because the incrementally recoverable fibers will be smaller in length. If twenty-five percent of the prevented emissions are recoverable, approximately 700 to 1,100 metric tons of low grade asbestos may be sold at approximately \$110 per metric ton (1980 dollars) for an annual benefit of \$77,000 to \$120,000 for the mills. The annual benefit could be twice this amount if half the incremental filter catch is of sufficient quality to be sold.

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<sup>45</sup>EPA, Comprehensive Study ..., p. 2-22.

## EXHIBIT 3-12

## ESTIMATES OF ASBESTOS MILL AIR EMISSIONS PREVENTED BY THE ASBESTOS NESHAP

| Year<br>(1)                                            | Production<br>(thousands<br>of metric tons) <u>a/</u><br>(2) | Annual Emissions<br>in the Absence<br>of the NESHAP <u>b/</u><br>(thousands<br>of metric tons)<br>(3) | Percent of<br>Emissions<br>Prevented <u>b/</u><br>(4) | Quantity of Emissions<br>Prevented (3) x (4)<br>(thousands <u>c/</u><br>of metric tons)<br>(5) |
|--------------------------------------------------------|--------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|-------------------------------------------------------|------------------------------------------------------------------------------------------------|
| 1974                                                   | 103                                                          | 5.1                                                                                                   | 62                                                    | 3.2                                                                                            |
| 1975                                                   | 89                                                           | 4.4                                                                                                   | 62                                                    | 2.7                                                                                            |
| 1976                                                   | 105                                                          | 5.2                                                                                                   | 96                                                    | 5.0                                                                                            |
| 1977                                                   | 92                                                           | 4.6                                                                                                   | 96                                                    | 4.4                                                                                            |
| 1978                                                   | 93                                                           | 4.6                                                                                                   | 96                                                    | 4.4                                                                                            |
| 1979                                                   | 93                                                           | 4.6                                                                                                   | 96                                                    | 4.4                                                                                            |
| 1980                                                   | 80                                                           | 3.3                                                                                                   | 96                                                    | 3.2                                                                                            |
| 2000                                                   | 150/50 <u>e/</u>                                             | 6.2/2.1                                                                                               | 96                                                    | 6.0/2.0                                                                                        |
| Average: 1974-1980                                     | 93.6                                                         | 4.5                                                                                                   | -                                                     | 3.9                                                                                            |
| Average: 1974-2000 <u>d/</u><br>(high production path) | 109                                                          | 4.7                                                                                                   | -                                                     | 4.4                                                                                            |
| Average: 1974-2000<br>(low production path) <u>d/</u>  | 72                                                           | 3.1                                                                                                   | -                                                     | 2.9                                                                                            |

a/Bureau of Mines, Asbestos, A Chapter from Mineral Facts and Problems, 1980 Edition, (Washington, D.C.: 1980 (Bulletin 671)).

b/See text for derivation. Figures are  $\pm 10$  percent.

c/Figures are at best  $\pm 25$  percent.

d/Linear approach to year 2000 production level assumed.

e/Estimates of potential high and low production paths by the year 2000.

All of the prevented air emissions will enter the environment eventually. The recovered asbestos may enter the air, water, or land during manufacturing, product use, or disposal. Most of it, however, will not remain "free asbestos." It will become part of an asbestos product, such as cement pipe, that will prevent individuals from being exposed to most of it as free asbestos. The remainder of the prevented emissions will enter the land as solid waste. This waste may present a human health risk; the assessment of which is beyond the scope of this effort. Therefore, the 2.9 to 4.4 thousand metric tons of asbestos air emissions prevented should be viewed as the upper bound of the "effectiveness" of the asbestos NESHAP in relation to asbestos mills. The use of these numbers will be discussed further in Section 3.2.4, Asbestos NESHAP Cost- Effectiveness Analysis.

#### The Asbestos Manufacturing Industry

The asbestos manufacturing industry, described in the cost analysis section, was divided into five main parts by EPA's Comprehensive Study.<sup>46</sup> Exhibit 3-13 displays EPA's asbestos air emission reduction estimates for these activities. The basis for these estimates is not provided, and therefore their accuracy cannot be evaluated. No other estimates of NESHAP mandated emission reductions for this industry are available.

The Comprehensive Study estimates are taken at face value and assumed to be correct. The predicted 1977 emission reduction appears to implicitly assume a five percent annual growth rate in each of the segments of the industry. As discussed in the cost section, and shown in Exhibit 3-11, the activity in this industry has actually declined since 1972. The U.S. Bureau of Mines predicts annual domestic consumption of asbestos to remain stable around 620 thousand metric tons for the next twenty years.<sup>47</sup> This is approximately 16 percent less than the consumption upon which the EPA estimates are based. The distribution of asbestos consumption among the various segments of asbestos manufacturing has also fluctuated substantially during the 1970s. However, it is also predicted that the distribution of domestic asbestos consumption will remain fairly stable over the twenty years.<sup>48</sup> Therefore, the only adjustment to EPA's estimates of asbestos emissions reductions for manufacturing will be to lower them each by sixteen percent. The annual emissions reduction becomes 84 percent of the predicted 731 metric tons, or 614 metric tons.

The Comprehensive Study reported that recovered fibers are of little or no value to asbestos manufacturers. Therefore, no adjustment is made for this.

#### 3.2.4 Asbestos NESHAP Cost-Effectiveness Analysis

Exhibit 3-14 summarizes the cost and effectiveness estimates for the asbestos NESHAP. The estimates in Exhibit 3-14 do not include:

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<sup>46</sup> Ibid., p. 2-34.

<sup>47</sup> Bureau of Mines, Asbestos, A Chapter..., op. cit., p. 14.

<sup>48</sup> Ibid., p. 14.

## EXHIBIT 3-13

EPA ESTIMATES OF ANNUAL ASBESTOS AIR EMISSION REDUCTIONS  
FOR THE ASBESTOS MANUFACTURING INDUSTRY

| Product Group     | Number<br>of<br>Plants | Uncontrolled<br>1970 Emissions<br>(metric tons) | 1977 Emissions<br>(metric tons) |                  | Annual<br>Reductions<br>(metric tons) |
|-------------------|------------------------|-------------------------------------------------|---------------------------------|------------------|---------------------------------------|
|                   |                        |                                                 | Without<br>Controls             | With<br>Controls |                                       |
| Asbestos Cement   | 48                     | 206                                             | 290                             | 58               | 232                                   |
| Floor Tile        | 18                     | 101                                             | 142                             | 28               | 114                                   |
| Friction Material | 30                     | 314                                             | 441                             | 88               | 353                                   |
| Asbestos Paper    | 29                     | 15                                              | 21                              | 2                | 19                                    |
| Asbestos Textiles | <u>34</u>              | <u>20</u>                                       | <u>28</u>                       | <u>15</u>        | <u>13</u>                             |
| Total             | 159                    | 656                                             | 922                             | 191              | 731                                   |

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Source: Research Triangle Institute, Comprehensive Study of Specified Air Pollution Sources to Assess the Economic Impact of Air Quality Standards: Asbestos, Beryllium, Mercury (Research Triangle Park, N.C.: 1972 [NTIS PB-222 858]) p. 1-6.



## EXHIBIT 3-14

SUMMARY OF COST AND EFFECTIVENESS MEASURES FOR THE ASBESTOS NESHAP a/

| Product<br>Group<br>(1) | Best<br>Estimate of<br>Annualized<br>Cost<br>(1980 dollars)<br>(2) | Best Estimate<br>of Annual<br>Asbestos Air<br>Emission Prevented<br>(metric tons)<br>(3) | Cost per metric<br>ton removed<br>(1980 dollars)<br>(2)+(3) |
|-------------------------|--------------------------------------------------------------------|------------------------------------------------------------------------------------------|-------------------------------------------------------------|
| Milling                 | \$230 thousand<br>( <u>+25</u> percent)                            | 2.9 to 4.4 thousand                                                                      | \$63<br>( <u>+50</u> percent)                               |
| Manufacturing           | \$3.3 million<br>( <u>+25</u> percent)                             | 614                                                                                      | \$4,900<br>( <u>+25</u> percent)                            |
| Total                   | \$3.5 million<br>( <u>+25</u> percent)                             | 3.5 to 5.0 thousand                                                                      | \$820<br>( <u>+50</u> percent)                              |

a/ See text for explanation.

- Costs imposed by the potential contribution that the NESHAP made to mill closings;
- Costs and emission reductions from industries not examined here that were affected by the NESHAP;
- The value of recovered asbestos at the mills, potentially \$77 to 120 thousand annually;
- Joint benefits in terms of reduced occupational exposures to asbestos and other particulates; and
- Joint benefits in terms of reduced ambient concentration of other particulates.

The fairly rough approximations presented do indicate that it is much more expensive to prevent air emissions from the manufacturing industry than the milling industry.

This large difference in the cost of preventing asbestos emissions from milling as opposed to manufacturing is offset significantly by the number of individuals potentially exposed to the emissions from the various sources. Exhibit 3-15 shows the results of a survey that found the number of people located near asbestos mines and mills to be approximately 94 thousand. The mill emissions occur in three major areas. To estimate roughly the effect that considering exposure has on the cost-effectiveness of the various control options, we assumed the emissions and populations are equally distributed among the three locations. The total amount of "asbestos exposure" prevented by the NESHAP from milling locations is 90 to 140 million person-tons annually.<sup>4\*</sup> The manufacturing emissions are concentrated primarily in eight major metropolitan areas. Again assuming equal distribution across locations, the total amount of "asbestos exposure" prevented is 820 million person-tons annually. This estimate does not include all the asbestos manufacturing locations and may be low. Also, the estimates can be sensitive to the assumption regarding the equal distribution of population and emissions prevented across major locations.

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<sup>4\*</sup>Person-tons are estimated by multiplying the population in each location by the emissions prevented in that area and summing across all locations. If population and emissions are uniformly distributed across the three major milling locations, then person-tons equals:

$$\frac{(94 \text{ thousand people})}{3 \text{ locations}} \times \frac{(2.9 \text{ to } 4.4 \text{ thousand metric tons of emission prevented})}{3 \text{ locations}}$$

$$\times 3 \text{ locations} = 90 \text{ to } 140 \text{ million person-tons.}$$

The emissions and population may not be uniformly distributed across the major milling locations. Therefore, this may be an over- or underestimate.

## EXHIBIT 3-15

ATMOSPHERIC EXPOSURE TO ASBESTOS IN THE VICINITY  
OF ASBESTOS INDUSTRIAL FACILITIES

| <u>Type of Facility</u> <sup>a/</sup> | <u>Population at Risk</u> <sup>b/</sup> |
|---------------------------------------|-----------------------------------------|
| Mines and Mills                       | 94 thousand                             |
| Manufacturing                         | 10.7 million                            |
| Cement Products                       | 1.6 million                             |
| Floor Tile                            | 1.4 million                             |
| Friction Material                     | 4.2 million                             |
| Paper                                 | 1.0 million                             |
| Textiles                              | 2.5 million                             |
| Total                                 | 10.8 million                            |

a/ Includes all mills, but only 50 to 90 percent of manufacturing facilities in each category.

b/ Population residing within 30 km. of mines and mills and within 5 km. of manufacturing plants. The estimate of the population residing near mines and mills is not sensitive to the distance chosen for comparison because the population density is low. The choice of the distance from manufacturing plants used to estimate the population exposed can greatly affect the results because the manufacturing plants are located in densely populated areas. These distances were chosen based on expected dispersion of asbestos in rural and urban areas.

Source: Benjamin E. Suta and Richard J. Levine, "Non-occupational Asbestos Emissions and Exposures," Asbestos Properties, Applications and Hazards, L. Michaels and S.S. Chissick eds. (New York: John Wiley and Sons, 1979), I, p. 183.

The estimates of numbers of individuals located "near" the asbestos mines and mills and manufacturing locations are taken from a study by Serta and Levine.<sup>50</sup> Although detailed Census information was used to develop the estimates, they may be suspect for several reasons. Census data do not reflect the movement of individuals in and out of areas for work, shopping, school, and the like. For example, low density manufacturing regions may be highly populated during the day. Therefore, the figures may not accurately represent the number of people exposed to the emissions from the sources examined here. Additionally, people spend most of their time indoors. Asbestos levels from industrial point source emissions may be much lower in homes than in the ambient air.

Finally, Serta and Levine used different sized areas for comparison around mills and manufacturing locations. This may be warranted due to the greater ease of dispersion around rural mills as opposed to urban manufacturing locations. However, the results are likely to be very sensitive to the choice of dispersion radius, particularly for manufacturing locations in high density urban areas. Therefore, the figures presented here should be considered very rough and for illustrative purposes only. The effects of considering the relative sizes of the populations at risk from the various sources on the relative cost-effectiveness of the control measures is described below. A more detailed estimate of potentially exposed individuals will be required for EPA's comprehensive review of all asbestos related hazards. Additionally, the level of exposure may vary across exposed populations, and this too could affect the relative cost-effectiveness of various control options. The incorporation of population at risk greatly reduces the variance between the cost of control in mills and manufacturing. Although these figures are very rough, Exhibit 3-16 shows that the cost-effectiveness of emission controls at mills is from \$1.6 to 2.6 thousand per million person-tons; for manufacturing it is approximately \$4.0 thousand per million person-tons (1980 dollars).

All the figures presented in this analysis represent the average cost-effectiveness of the regulation. Individual product category cost-effectiveness analyses could be constructed by breaking down the aggregate cost-effectiveness estimate for the asbestos products manufacturing industry into the various industry segments. The cost-effectiveness of controlling emissions from each segment could be calculated; thereby identifying the industry segments for which it is most expensive to control asbestos air emissions. These results could be used to generate a marginal cost-effectiveness curve, assuming the emission control requirements could be imposed on one industry segment at a time. Primary data collection would be required to accomplish such an analysis.

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<sup>50</sup> Benjamin E. Serta and Richard J. Levine, "Non-occupational Asbestos Emissions and Exposures," Asbestos Properties, Applications and Hazards, L. Michaels and S.S. Chissick, eds. (New York: John Wiley and Sons, 1979), I, p. 183.



## EXHIBIT 3-16

COST-EFFECTIVENESS ESTIMATES IN TERMS OF DOLLARS PER PERSON-TON  
OF ASBESTOS EMISSIONS PREVENTED

| Industry<br>(1) | Emissions<br>Prevented<br>(metric tons)<br>(2) | Population<br>at Risk<br>(3) | Number<br>of Major<br>Locations<br>(4) | Person-tons<br>of Emissions<br>Prevented<br>(5) | Compliance<br>Costs<br>(1980\$)<br>(6) | Cost Per Million Person-tons<br>of Emissions Prevented<br>(thousands of 1980 dollars)<br>(7) |
|-----------------|------------------------------------------------|------------------------------|----------------------------------------|-------------------------------------------------|----------------------------------------|----------------------------------------------------------------------------------------------|
| Milling         | 2900 to 4400                                   | 94,000                       | 3                                      | <sup>a/</sup><br>90 to 140<br>million           | \$230 thousand                         | 1.6 to 2.6                                                                                   |
| Manufacturing   | 614                                            | 10.7 million                 | 8                                      | <sup>a/</sup><br>820 million                    | \$3.3 million                          | 4.0                                                                                          |
| TOTAL           | 3500 to 5000                                   | 10.8 million                 | 11                                     | <sup>b/</sup><br>910 to 960<br>million          | \$3.5 million                          | 3.6 to 3.8                                                                                   |

<sup>a/</sup> Calculated as follows: (2) x (3) / (4)<sup>b/</sup> Calculated by summing estimates for milling and manufacturing.

An alternative or complementary approach to marginal analysis would be to examine the costs of a less strict standard. This may not be a viable option in this case because the "no visible emissions" requirement is not a numerical measure against which a relaxation of the standard could be measured. Even if accurate monitoring and a numerical approach to control were tractable, the evidence reviewed for the preparation of this report suggests that the least costly control alternative in the likely relevant range of emission reduction requirements is the one examined for the NESHAP. Therefore, the costs identified here may be viewed as the "average incremental costs of controlling asbestos air emissions to any significant degree."

### 3.3 ASBESTOS INDUSTRY EFFLUENT LIMITATIONS GUIDELINES

#### 3.3.1 Introduction

In 1974 and 1975 EPA promulgated Effluent Limitations Guidelines for the Asbestos Industry (Guidelines).<sup>§1</sup> The Guidelines, required under the Clean Water Act, are used in the state or regional implementation of the NPDES<sup>§2</sup> permit program to specify effluent requirements for individual dischargers. Effluent quality requirements defined in discharge permits may vary from those published in the Guidelines when local conditions warrant. However, all variances must be approved by the EPA Administrator.

The Guidelines specify effluent quality requirements by defining the effluent quality obtainable with the technologies required by Congress in the Act. By 1977, existing asbestos manufacturing point sources were required to meet or exceed the effluent quality obtained by the "best practicable control technology currently available" (BPT). By 1984 (originally 1983), these same sources will be required to meet or exceed the effluent quality obtained by the "best available technology economically achievable" (BAT). Additionally, new sources are required to meet New Source Performance Standards, and existing sources discharging to publicly owned treatment works must meet Pretreatment Standards. This report focuses on the major portions of the Guidelines, the BPT and BAT definitions.

Similar to the NESHAP discussed in the previous section, the Guidelines do not define a numerical limit for asbestos water emissions. Instead, water quality in terms of total suspended solids (TSS) is defined, the achievement of which reduces total asbestos emissions to water. The Guidelines may be characterized as controlling a wide range of suspended and dissolved solids, a portion of which is asbestos. Therefore, there were no estimates of the quantity of asbestos emissions that would be prevented by the regulation. Information on the quantity of asbestos relative to total solids is used to estimate the total amount of asbestos emissions prevented by the Guidelines. It is assumed that no significant variances from the Guidelines were requested and approved, and that the major sources required to comply with BPT have done so.

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<sup>§1</sup>40 CFR 427.

<sup>§2</sup>National Pollutant Discharge Elimination System authorized under Section 402 of the Clean Water Act.

Again, as with the NESHAP, measurement difficulties create uncertainty in estimates of asbestos concentration in effluent. The number of fibers per liter found in a water sample depends to a great extent on "how hard one looks;" i.e., the magnification at which the sample is examined, the particular type of asbestos and the individual performing the analysis. Conversions from measurements in "fibers per liter" to "grams per liter" are also uncertain because they depend on the distribution of fiber lengths in the sample and the method used to count fibers. Therefore, estimates of numbers of tons of asbestos emissions prevented are necessarily reported as large ranges.

A series of Development Documents and Economic Analyses prepared by EPA in support of the Guidelines provide the majority of the data used here. Additionally, some more recent information on the asbestos industry collected by EPA in support of its current asbestos investigations is also available. Other independent sources including the Bureau of Mines are also used.

### 3.3.2 Asbestos Guidelines Cost Analysis

The Guidelines for Asbestos Manufacturing Point Sources are divided into the following eleven categories:<sup>53</sup>

- A. Asbestos-Cement Pipe;
- B. Asbestos-Cement Sheet;
- C. Asbestos Paper (Starch Binder);
- D. Asbestos Paper (Elastomeric Binder);
- E. Asbestos Millboard;
- F. Asbestos Roofing;
- G. Asbestos Floor Tile;
- H. Coating or Finishing of Asbestos Textiles;
- I. Solvent Recovery;
- J. Vapor Absorption; and
- K. Wet Dust Collection.

No cost information is available on the last three categories, which are small relative to the others, so they are excluded. There are no known asbestos textile plants discharging asbestos contaminated water into navigable waters, and the pretreatment standards for the plants discharging to publicly owned treatment works have no limitations on suspended solids or asbestos.<sup>54</sup> Therefore, textiles are also excluded. The paper categories were investigated together and have identical BAT and BPT requirements, only their New Source Performance standards differ. The paper categories are therefore combined, resulting in six separate categories:

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<sup>53</sup>40 CFR 427.

<sup>54</sup>No limitations were set in the Pretreatment Standards because publicly owned treatment works have sufficient sedimentation capacity to handle the discharge, and effluent from sources covered here does not include toxics that would upset the operation of the treatment plants.

- Asbestos-Cement Pipe;
- Asbestos-Cement Sheet;
- Asbestos Paper;
- Asbestos Millboard;
- Asbestos Roofing; and
- Asbestos Floor Tile.

Two sources predicted the costs of compliance with BPT and BAT for these industry segments, the Development Document (EPA 1974)<sup>55</sup> and the Economic Analysis (EPA 1974).<sup>56</sup> The two documents appear to be based on the same or similar data and should not be considered independent. The Development Document calculated costs for each industry segment by estimating the cost of compliance for a "typical plant" in each segment and then extrapolating to all plants in the industry. The Economic Analysis also based cost estimates on the engineering requirements for a "typical plant." However, the Economic Analysis had additional information which enabled extrapolation to total industry costs based on data reflecting the actual effluent quantity and quality at each known location. Therefore, the Economic Analysis estimates may be more accurate.

Exhibit 3-17 displays the estimated compliance costs reported in these two studies. The BAT compliance cost estimates are for up-grading to BAT standards without BPT intermediate. The estimates are generally similar and within about thirty percent of each other. A notable exception is asbestos millboard manufacturing for which the Development Document estimate is approximately twice that of the Economic Analysis. The Economic Analysis cost estimates are based on effluent data from individual establishments that account for nearly 100 percent of total industry shipments in each segment. As shown in Exhibit 3-18, only the asbestos floor tile segment is not fully or nearly fully covered.

The baseline for the compliance cost estimates shown in Exhibit 3-17 is current practices in 1974. The existing control technology for each plant was identified and categorized as one of the following:

- No treatment;
- Sedimentation only;
- Sedimentation and pH control (applicable only for asbestos-cement pipe and sheet segments); and
- 100 percent recycle, no discharge.

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<sup>55</sup>EPA, Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Building, Construction, and Paper Segment of the Asbestos Manufacturing Point Source Category (Washington, D.C.: February 1974 [NTIS PB-238 320]).

<sup>56</sup>A.D. Little, Economic Analysis of Effluent Guidelines for the Asbestos Industry (Massachusetts: December 1974 [NTIS PB-238 268]).



## EXHIBIT 3-17

ESTIMATED ANNUALIZED COMPLIANCE COSTS FOR BPT AND BAT  
(Thousands of 1971 dollars)

| Industry Segment      | BPT <sup>a/</sup>       |                      | BAT <sup>a/</sup>       |                      |
|-----------------------|-------------------------|----------------------|-------------------------|----------------------|
|                       | Development Document b/ | Economic Analysis c/ | Development Document b/ | Economic Analysis c/ |
| Asbestos-Cement Pipe  | \$470                   | \$345                | \$760                   | \$604                |
| Asbestos-Cement Sheet | 440                     | 472                  | 980                     | 1,152                |
| Asbestos Paper        | 125                     | 190                  | 400                     | 600                  |
| Asbestos Millboard    | 191                     | 90                   | 191 d/                  | 90 d/                |
| Asbestos Roofing      | 50                      | 47                   | 37                      | 69                   |
| Asbestos Floor Tile   | 195                     | 245                  | 310                     | 357                  |
| Total                 | \$1,471                 | \$1,389              | \$2,678                 | \$2,872              |

<sup>a/</sup> BPT = Best practicable control technology currently available.

BAT = Best available technology economically achievable.

<sup>b/</sup> EPA, Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Building, Construction, and Paper Segments of the Asbestos Manufacturing Point Source Category (Washington, D.C.: February 1974 CNTIS PB-238 320f).

<sup>c/</sup> A.D. Little, Economic Analysis of Effluent Guidelines for the Asbestos Industry (Massachusetts: December 1974 [NTIS PB-238 268]).

<sup>d/</sup> BPT and BAT are the same for Asbestos Millboard manufacturing.

## EXHIBIT 3-18

PROPORTION OF TOTAL INDUSTRY SEGMENT SHIPMENTS  
ACCOUNTED FOR BY LOCATIONS EXAMINED IN ECONOMIC ANALYSIS<sup>a/</sup>

| <u>Industry Segment</u> | <u>Percentage of Shipments Covered</u> |
|-------------------------|----------------------------------------|
| Asbestos-Cement Pipe    | 95-100                                 |
| Asbestos-Cement Sheet   | 90-95                                  |
| Asbestos Paper          | 95-100                                 |
| Asbestos Millboard      | 95-100                                 |
| Asbestos Roofing        | 95-100                                 |
| Asbestos Floor Tile     | 60-70                                  |

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<sup>a/</sup> Year is not reported.

Source: A.D. Little, Economic Analysis of Effluent Guidelines for the Asbestos Industry (Massachusetts: December 1974 [NTIS PB-238 268]), p. 44.

The incremental cost of meeting BPT and BAT for each plant was estimated, and these estimates were summed to generate total industry costs. Exhibit 3-19 displays the percentage of known plants having the various levels of treatment in 1974. Plants in each segment were at various levels of treatment at that time and it is possible that movement toward increased treatment may have occurred in the absence of the Guideline requirements. Therefore, the compliance cost estimates in Exhibit 3-17 are upper bounds, and could be adjusted downward. The extent to which these are overestimates cannot be determined, however.

The compliance cost estimates in Exhibit 3-17 are also overestimated because, as mentioned in the NESHAP analyses in Section 2 and shown in Exhibit 3-11, activity in the asbestos manufacturing industry has decreased since the early- and mid-1970s. Operation and maintenance costs of control equipment would be less than predicted due to reduced production. Current domestic asbestos consumption is about sixteen percent less than the pre-1974 average rate upon which the standards are presumably based. If operation and maintenance costs vary directly with asbestos consumption (which is probably an overestimate), and if operation and maintenance make up approximately fifty percent of total annualized costs,<sup>57</sup> then the Economic Analysis cost estimate may be overestimated by as much as eight percent. This potential error is too small to warrant an adjustment of the estimates presented here which are already uncertain.

The Economic Analysis also examined the effects the Guidelines would have on prices, plant closures, employment, industry growth, balance of trade, and communities. Only the asbestos millboard segment was expected to be adversely affected with two of seven plants potentially closing down and 240 employees losing their jobs because of BPT compliance requirements. These two fairly small plants were predicted to incur compliance costs equal to 4.9 and 3.5 percent of their annual sales (most other plants were under one percent). No other significant adverse effects were predicted.

There are no retrospective analyses or data to confirm whether these or other plants were closed by the regulations. Individuals who become unemployed may have been able to find new employment fairly quickly because no adverse community impacts (measured in economic terms) were predicted. Assuming 240 individuals were unemployed for three to six months as a result of the regulations, and valuing their unemployment time at their previous median annual wage rate of \$7,700 (1971 dollars),<sup>58</sup> approximately \$460 to \$920 thousand in lost wages may have resulted from the standards. These lost wages are policy relevant distributional impacts, but may not necessarily represent additional social costs. Clearly there are costs associated with

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<sup>57</sup> Ibid, pp. 75-80.

<sup>58</sup> Bureau of Labor Statistics, Annual Earnings and Employment Patterns of Private Nonagricultural Employees, 1971 and 1972 (Washington, D.C.: 1976 [Bulletin 1928], p. 18.

## EXHIBIT 3-19

BASELINE OF TREATMENT TECHNOLOGIES FOR  
GUIDELINES COMPLIANCE COST ESTIMATES

| Industry<br>Segment   | Percentage of Plants<br>Using Treatment<br>Technologies |                 |                 |                 | Percentage of Discharge<br>Treated by Technologies |    |    |                 |
|-----------------------|---------------------------------------------------------|-----------------|-----------------|-----------------|----------------------------------------------------|----|----|-----------------|
|                       | A                                                       | B <sup>b/</sup> | C <sup>c/</sup> | D <sup>d/</sup> | A                                                  | B  | C  | D <sup>a/</sup> |
| Asbestos-Cement Pipe  | 14                                                      | 43              | 29              | 14              | 16                                                 | 43 | 41 | -               |
| Asbestos-Cement Sheet | 38                                                      | 38              | 9               | 15              | 41                                                 | 51 | 8  | -               |
| Asbestos Paper        | 14                                                      | 57              | -               | 29              | 21                                                 | 79 | -  | -               |
| Asbestos Millboard    | 29                                                      | 43              | -               | 28              | 38                                                 | 62 | -  | -               |
| Asbestos Roofing      | 56                                                      | 33              | -               | 11              | 44                                                 | 56 | -  | -               |
| Asbestos Floor Tile   | 77                                                      | 23              | -               | 0               | 61                                                 | 39 | -  | -               |

A = No treatment.

B = Sedimentation.

C = Sedimentation and pH control (applicable only for asbestos-cement pipe and sheet).

D = 100 percent recycle, no discharge.

a/ Although not specifically stated, it is assumed that no percentage of discharge is listed as treated by 100 percent recycle because there is no discharge from that treatment technology.

b/ BPT for Paper, Roofing and Floor Tile Segments.

c/ BPT for Pipe and Sheet segments.

d/ BPT for Millboard and BAT for all segments.

Source: A.D. Little, Economic Analysis of Effluent Guidelines for the Asbestos Industry (Massachusetts: December 1974 [NTIS PB-238 268]), p. 33-34.



transitional unemployment caused by regulations, such as, searching for a new job, training, and anxiety. However, the exact magnitude of these costs is not known and the lost wages may not be a representative estimate of the cost of unemployment. Therefore, although unemployment costs may be significant relative to the total costs of control in the asbestos millboard segment, they are not included in the analysis.

There is insufficient information to assess any other costs relating to the plant closures. The asbestos products industry is rather mature and the equipment stock is fairly old. There may have been little or no salvage value for the equipment at the two plants that may have closed. Therefore, other costs of plant closure, for example the loss of productive equipment, will be excluded here.

Exhibit 3-20 shows revised compliance cost estimates and ranges for accuracy. We derived the estimates by taking a weighted average of the Development Document and Economic Analysis estimates shown in Exhibit 3-17. The Economic Analysis figures were given twice the weight as the Development Document estimates because of the more thorough nature of its extrapolation of typical plant costs to industry totals. It was believed best not to disregard the EPA estimates entirely. For consistency of presentation in this report all figures are adjusted to 1980 dollars.

To improve these estimates of compliance costs, primary data collection is required. Actual expenditures on pollution control equipment at the various plants is needed. Also, historical data on pre-1974 pollution control expenditures could be useful in improving the baseline estimate; as would discussions with industry experts.

### 3.3.3 Asbestos Guidelines Effectiveness Analysis

Although, as mentioned above, the Guidelines are designed to control several pollutants including Chemical Oxygen Demand (COD), pH, and total suspended solids (TSS), a large quantity of asbestos emissions are also prevented. The costs outlined in the previous section reflect the cost of removing all the various pollutants from the water effluent of asbestos manufacturing point sources. This section concentrates only on the benefits of removing the asbestos. The next section, Cost-Effectiveness Analysis, discusses the difficulties associated with attributing portions of the total cost to the benefits of asbestos control examined below.

It has not been established to what extent ingested asbestos may be harmful.<sup>55</sup> The discovery of large amounts of asbestos fibers in Lake

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<sup>55</sup>R.J. Levine, M.D. Gidley et al., "Asbestos-Related Diseases. Part 5. The Prevention of Asbestos-Related Disease," Asbestos Properties, Applications and Hazards, L. Michaels and S.S. Chissick eds. (New York: John Wiley and Sons, 1979), I, p. 498.

## EXHIBIT 3-20

COMPOSITE ANNUALIZED COMPLIANCE COST ESTIMATES  
 FOR BPT AND BAT a/  
 (Thousands of 1980 dollars)

| Industry Segment      | BPT              |                     | BAT               |                       |
|-----------------------|------------------|---------------------|-------------------|-----------------------|
|                       | Average Estimate | Range <sup>b/</sup> | Average Estimate  | Range <sup>b/</sup>   |
| Asbestos-Cement Pipe  | 720              | 650-880             | 1200              | 1100-1400             |
| Asbestos-Cement Sheet | 860              | 820-880             | 2000              | 1800-2150             |
| Asbestos Paper        | 320              | 230-350             | 1000              | 790-1100              |
| Asbestos Millboard    | 230              | 170-360             | 230 <sup>c/</sup> | 170-360 <sup>c/</sup> |
| Asbestos Roofing      | 90               | 85-93               | 110               | 70-130                |
| Asbestos Floor Tile   | <u>425</u>       | 360-460             | <u>640</u>        | 580-660               |
| Total                 | 2645             | -                   | 5180              | -                     |

a/ See text for derivation.

b/ Reflects range of the Development Document and Economic Analysis estimates.  
 Ten percent confidence intervals may be larger.

c/ BPT and BAT are the same for Asbestos Millboard manufacturing.

Superior and the drinking water supply of Duluth, Minn. focused attention on the problem in the early 1970s.<sup>60</sup> Since that time several animal feeding studies were undertaken with mixed results. Malignancies were observed of the kidneys, gastrointestinal tract, and other locations. The limited number of animals studied to date leave the evidence for carcinogenicity of asbestos inconclusive.<sup>61</sup>

Five studies have considered the relation of asbestos ingested in drinking water to gastrointestinal cancer in humans.<sup>62</sup> The results of these investigations were also mixed; two showing a positive dose-response relationship, two showing no significant relationship, and one inconclusive.<sup>63</sup> Despite the remaining uncertainty, it is the opinion of some researchers that the oral intake of asbestos should be reduced as much as possible.<sup>64</sup> Nevertheless, quantitative estimates of health benefits from reductions of asbestos in water cannot be made.

Asbestos fibers have been found in the drinking water of numerous cities throughout the United States. Exhibit 3-21 shows the results of samples taken from 365 cities nationwide. The detection method employed to generate Exhibit 3-21 was not reported, and because of the large potential variability of detection methods, the results should be used with caution. Nevertheless, the data demonstrate that over forty percent of the water supplies sampled are contaminated with measurable quantities of asbestos fibers.

The contribution that the asbestos emissions controlled by the Guidelines would have made to the contamination of drinking water supplies and other sources of human exposure has not been estimated. Asbestos in water may come from air emissions, water emissions, product use, and disposal to land as well as natural erosion. The effect that the Guidelines have had on human exposure to asbestos is not known. Therefore, statements regarding the percentage reduction of risk to humans from asbestos in water brought about by the Guidelines cannot be made.

The benefits of the regulation are measured in terms of the number of metric tons of asbestos emissions prevented annually. Emission reduction estimates are derived from several sources including the Development Document and the Economic Analysis cited in the cost section and an analysis of

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<sup>60</sup>EPA, Ambient Water Quality Criteria for Asbestos (Washington, D.C.: October 1980 [NTIS PB81-117335]), p. C-40.

<sup>61</sup> Ibid, p. C-45.

<sup>62</sup> Ibid, p. C-45.

<sup>63</sup> Ibid, pp. C-64, C-65, C-66, C-67.

<sup>64</sup>Levine, op. cit., pp. 498-499.

## EXHIBIT 3-21

DISTRIBUTION OF REPORTED ASBESTOS CONCENTRATIONS IN  
DRINKING WATER FROM 365 CITIES IN 43 STATES,  
PUERTO RICO, AND THE DISTRICT OF COLUMBIA

| Asbestos Concentration<br>(10 <sup>6</sup> fibers/liter) | Number of Cities | Percentage of<br>Samples |
|----------------------------------------------------------|------------------|--------------------------|
| <u>a/</u><br>Below Detectable Limits                     | 110              | 30.1                     |
| Not Statistically Significant                            | 90               | 24.7                     |
| Less than 1.0                                            | 90               | 24.7                     |
| 1.0 to 10.0                                              | 34               | 9.3                      |
| Greater than 10                                          | <u>41</u>        | <u>11.2</u>              |
|                                                          | 365              | 100.0                    |

a/ Average detectable limits were  $5 \times 10^5$  fibers per liter; but quantities varied due to presence of non asbestos fibers.

Source: EPA, Ambient Water Quality Criteria for Asbestos (Washington, D.C.: October 1980 [NTIS PB81-117335]), p. c-14.



asbestos concentrations in manufacturing point source emissions (Concentrations Analysis).<sup>66</sup> The baseline for the analysis is the same as displayed in Exhibit 3-19 and used in the cost analysis. Exhibit 3-22 shows the asbestos concentrations expected from plants with or without treatment in each of four industry segments. These estimates were developed by calculating the average concentration for each plant sampled, and then averaging the averages across plants in each industry segment. The sample concentrations were highly variable across plants, and the average figures reported may not reflect the effluent quality of an individual plant. However, within reasonable ranges of uncertainty, the estimates in Exhibit 3-22 are believed to be representative of the effluent for each industry segment.

Many of the samples reported in the Concentration Analysis had an indeterminate number of total asbestos fibers because the fibers were too numerous to count by available methods. Total fibers for these samples were estimated by assuming that fibers greater than five microns comprise one-tenth of all fibers in the samples.<sup>67</sup> Additionally, the cement product effluent reportedly included fiber-like material bound in concrete. These particles were not counted as free asbestos fibers, which may account for the magnitude difference in concentrations between the cement products effluent and the paper and millboard effluent shown in Exhibit 3-22.

The number of metric tons of asbestos emissions prevented annually by the Guidelines was estimated as follows:

- Estimate the total annual discharge at each of three levels of treatment for each industry segment (treatment levels are those shown in Exhibit 3-19: No treatment; Sedimentation; and Recycle);
- Multiply the effluent asbestos concentrations by the appropriate effluent quantities to estimate the asbestos fiber emissions prevented by BPT and BAT for each industry segment; and
- Convert numbers of asbestos fibers to estimates of fiber mass to calculate metric tons of asbestos emissions prevented.

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<sup>66</sup>McCrone Associates, Asbestos Fibers in Natural Runoff and Discharges from Sources Manufacturing Asbestos Products. Pt. II-Non-Point Sources and Point Sources Manufacturing Asbestos Products (Chicago, Ill.: October 1976 [NTIS PB-263 746]).

<sup>67</sup>The true distribution of fiber sizes depends on the grade of asbestos used. The estimated distribution depends on the detection method used; the greater the magnification, the more small fibers will be found and the smaller the percentage of large fibers greater than five microns. The one-tenth figure is an average for settled asbestos contaminated water and may be a slight overestimate for nontreated effluent.

## EXHIBIT 3-22

ESTIMATED ASBESTOS CONCENTRATION IN WATER EFFLUENT <sup>a/</sup>  
(10<sup>6</sup> fibers per liter)

| Industry Segment      | Treatment Technology in Use |               |
|-----------------------|-----------------------------|---------------|
|                       | No Treatment                | Sedimentation |
| Asbestos-Cement Pipe  | 90,000                      | 1,200         |
| Asbestos-Cement Sheet | 300,00                      | 1,300         |
| Asbestos Paper        | 2,000,000                   | 37,000        |
| Asbestos Millboard    | 1,000,000                   | 37,000        |

a/ See text for derivation.

Source: McCrone Associates, Asbestos Fibers in Natural Runoff and Discharges from Sources Manufacturing Asbestos Products. Pt. II-Non-Point Sources and Point Sources Manufacturing Asbestos Products (Chicago, Ill.: October 1976 [NTIS PB-263 746]).

Estimates of total industry discharge are taken from the Economic Analysis which reports that it accounts for nearly all discharges affected by the Guidelines.

Conversion from fiber counts to estimates of asbestos mass is also a source of considerable uncertainty. Again, appropriate values depend on the distribution of fiber sizes in the sample and the detection method used to count fibers. An average value for site runoff and untreated water discharge is used here; 0.05 micrograms per million fibers of all lengths.<sup>67</sup> Other reported values include a low of 0.002 micrograms per million fibers from natural erosion,<sup>68</sup> to values as high as 0.1 to 10.0 micrograms per million fibers from unnamed sources.<sup>69</sup> This very wide range of values highlights the difficulties inherent in evaluating the effectiveness of asbestos control measures. The value adopted here is probably reasonable for the effluents being examined, however it could easily be under- or overstated by one order of magnitude.

Exhibit 3-23 displays estimates of asbestos required to be removed from water effluent by the Guidelines. Additionally, estimates of other solids removed at the same time are also shown. Quantities of other solids removed were calculated in a manner similar to that used for asbestos, however, fiber to mass conversions were not required because concentrations were given in milligrams per liter. Exhibit 3-23 demonstrates that asbestos removal is a small portion of total solids removed, and that the incremental asbestos reduction achieved by going from BPT to BAT is very small.

These results must be interpreted carefully; there are many uncertainties in the development of the estimates and an appropriate range to consider may be as large as plus or minus one magnitude. Additionally, the Guidelines do not require the destruction of asbestos, only its removal from water effluent. Generally, the asbestos is diverted to land disposal. However, air and water emissions may result. For example, at several locations with sedimentation treatment of effluent, sludge was piled on site and then hauled away. The sludge pile, containing asbestos, was exposed to the elements, and during heavy rains was partially washed into the effluent stream below the treatment facility. The extent to which asbestos that is removed from water effluents is diverted back to land, air, and water is not considered here. This asbestos, although originally removed from effluent streams, may pose health risks.

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<sup>67</sup>EPA, Ambient Water Quality ..., op. cit., p. c-18.

<sup>68</sup> Ibid, p. c-18.

<sup>69</sup>Benjamin E. Suta and Richard L. Levine, "Non-occupational Asbestos Emissions and Exposures," Asbestos Properties, Applications, and Hazards, L. Michaels and S.S. Chissick eds. (New York: John Wiley and Sons, 1979), I, p. 183.

## EXHIBIT 3-23

ESTIMATES OF ASBESTOS AND OTHER SOLIDS REMOVED  
ANNUALLY BY BPT AND BAT REQUIREMENTS a/

| Industry<br>Segment      | Annual<br>Discharge<br>(10 <sup>6</sup> Liters) <u>b/</u> | Material Removed (metric tons) |                 |                     |                     |
|--------------------------|-----------------------------------------------------------|--------------------------------|-----------------|---------------------|---------------------|
|                          |                                                           | BPT                            |                 | BAT <u>c/</u>       |                     |
|                          |                                                           | Asbestos                       | Other<br>Solids | Asbestos            | Other<br>Solids     |
| Asbestos-Cement<br>Pipe  | 2.83                                                      | 2                              | 210             | 2(+)                | 500                 |
| Asbestos-Cement<br>Sheet | 1.74                                                      | 11                             | 575             | 33                  | 2575                |
| Asbestos Paper           | 5.02                                                      | 105                            | 600             | 107                 | 6600                |
| Asbestos<br>Millboard    | <u>1.26</u>                                               | <u>24</u>                      | <u>20</u>       | <u>24</u> <u>d/</u> | <u>20</u> <u>d/</u> |
| TOTAL                    | 10.85                                                     | 142                            | 1405            | 166                 | 9659                |

a/ See text for derivation.

b/ Source: A.D. Little, Economic Analysis of Effluent Guidelines For the Asbestos Industry (Massachusetts: December 1979 [NTIS PB-238 268]), p. 34. Based on 250 working days per year.

c/ Assumes single-step up-grading to BAT without BPT intermediate.

d/ BPT and BAT requirements are identical for Asbestos Millboard.



Estimates of the quantity of asbestos removed from effluents could be improved by primary data collection similar to that required to improve the cost estimates. However, it is unlikely that benefits in terms of human health effects can be estimated at this time.

### 3.3.4 Asbestos Guidelines Cost-Effectiveness Analysis

This section combines the cost and benefit estimates described in the previous two sections and develops a cost-effectiveness measure for the removal of asbestos from manufacturing point sources. Four segments of the industry are examined, Asbestos-Cement Pipe, Asbestos-Cement Sheet, Asbestos Paper, and Asbestos Millboard. The other two segments for which compliance costs were estimated, Asbestos Roofing and Asbestos Floor Tile, are omitted because insufficient data were available to estimate benefits. Cost-effectiveness is reported in dollars per ton of asbestos emission prevented annually (1980 dollars).

The cost estimates reported earlier must be adjusted because they include the cost of controlling other pollutants. Approximately 40 percent of the BPT costs for the pipe and sheet segments is attributable directly to pH control, which does not affect the amount of asbestos or other pollutants discharged.<sup>70</sup> Therefore, these estimates can be reduced by 40 percent. Reduction of pH is required for the achievement of BAT, no discharge, for these two segments. Without pH control the BAT reduction in asbestos and other solids emissions could not be obtained. Therefore, portions of BAT costs cannot be attributed solely to pH control and the estimates are not adjusted downward.

The costs of control may also be distributed between the asbestos and other solids controlled.<sup>71</sup> There is no single correct division of control costs among the constituents because controlling one pollutant necessarily controls the other. Were there no benefits of controlling the other solids, they could be ignored and all costs could be attributed to asbestos control. However, solids discharges have a variety of adverse effects including:<sup>72</sup>

- Interference with drinking water treatment processes;
- Interference with industrial water usage;
- Potential depletion of dissolved oxygen and the production of noxious gas; and
- Disruption of fisheries.

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<sup>70</sup>EPA, Development Document ..., op. cit., pp. 80-87.

<sup>71</sup>A small amount of COD is also controlled in the roofing and floor tile categories which are excluded here.

<sup>72</sup>EPA, Development Document ..., op. cit., pp. 58-59.

Therefore, some attribution of costs to the two primary pollutants controlled is required.

Exhibit 3-24 displays one estimate of the cost-effectiveness of the guidelines. The costs are allocated among the asbestos and other solids controlled simply on the basis of the percentage of total pollutants controlled by weight. If asbestos makes up 20 percent of the total solids controlled, then 20 percent of the costs are attributed to asbestos control. Using this allocation scheme, the industry segments could be ranked according to the cost-effectiveness of BPT as follows:

- 1) Asbestos Paper;
- 2) Asbestos Cement Sheet;
- 3) Asbestos Cement Pipe; and
- 4) Asbestos Millboard.

An alternate method for allocating costs is on the basis of the amount of total "hazard" removed. A common unit of hazard is required, and for each amount of waste controlled (e.g., tons of asbestos removed) one calculates an equivalent amount of hazard removed. The hazard rating for individual substances (such as asbestos in water) depends on its toxic properties, persistence, biodegradability, potential for human exposure, and other factors.<sup>73</sup>

Rating the hazard posed by the effluents controlled by the Guidelines is beyond the scope of this study. Nevertheless, for illustrative purposes we have assumed the following:

- One metric ton of asbestos emissions equals 100 units of hazard; and
- One metric ton of other solids emissions from each of the industry segments equals 1 unit of hazard.

Therefore, the asbestos emissions are "100 times more hazardous" than the emissions of the other solids. Exhibit 3-25 displays the cost-effectiveness of the Guidelines scaled according to the amount of hazard removed.

Using the hazard scale cost allocation method, the industry segments could be ranked according to the cost-effectiveness of BPT as follows:

- 1) Asbestos Paper;
- 2) Asbestos Millboard;
- 3) Asbestos Cement Sheet; and
- 4) Asbestos Cement Pipe.

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<sup>73</sup>See November 28, 1980 Federal Register for more detail on EPA's development of a hazard scale.

## EXHIBIT 3-24

ESTIMATES OF COST-EFFECTIVENESS OF BPT AND BAT  
ASBESTOS REMOVAL

| Industry Segment<br>(1)            | Metric Tons of Asbestos Removed Annually<br>(2) | Percentage of Total Solids Removed<br>(3) | Total Compliance Cost (1000 of 1980 \$)<br>(4) | Cost Per Ton of Asbestos Removed (3)x (4)+(2) (1000 of 1980 \$)<br>(5) |
|------------------------------------|-------------------------------------------------|-------------------------------------------|------------------------------------------------|------------------------------------------------------------------------|
| Asbestos-Cement Pipe               |                                                 |                                           |                                                |                                                                        |
| BPT                                | 2                                               | 0.9                                       | <sup>a/</sup> 440                              | 2.1                                                                    |
| BAT                                | 2.0(+)                                          | 0.4                                       | 1200                                           | 2.4                                                                    |
| BAT - BPT<br>(Incremental Control) | <sup>b/</sup> (0.034)                           | 0.01                                      | 760                                            | 2.6                                                                    |
| Asbestos-Cement Sheet              |                                                 |                                           |                                                |                                                                        |
| BPT                                | 11                                              | 1.8                                       | <sup>a/</sup> 520                              | 0.90                                                                   |
| BAT                                | 33                                              | 1.3                                       | 2000                                           | 0.77                                                                   |
| BAT - BPT<br>(Incremental Control) | 11                                              | 1.1                                       | 1480                                           |                                                                        |
| Asbestos Paper                     |                                                 |                                           |                                                |                                                                        |
| BPT                                | 105                                             | 15.                                       | 320                                            | 0.45                                                                   |
| BAT                                | 107                                             | 1.6                                       | 1000                                           | 0.15                                                                   |
| BAT - BPT<br>(Incremental Control) | 2                                               | 0.03                                      | 680                                            | 0.11                                                                   |

Continued on next page.

## EXHIBIT 3-24

ESTIMATES OF COST-EFFECTIVENESS OF BPT AND BAT  
ASBESTOS REMOVAL  
(continued)

| Industry Segment<br>(1)            | Metric Tons of Asbestos Removed Annually<br>(2) | Percentage of Total Solids Removed<br>(3) | Total Compliance Cost (1000 of 1980 \$)<br>(4) | Cost Per Ton of Asbestos Removed (3)x (4)÷(2) (1000 of 1980 \$)<br>(5) |
|------------------------------------|-------------------------------------------------|-------------------------------------------|------------------------------------------------|------------------------------------------------------------------------|
| Asbestos Millboard                 |                                                 |                                           |                                                |                                                                        |
| BPT/BAT <sup>c/</sup>              | 24                                              | 55.1                                      | 230                                            | 5.3                                                                    |
| Total                              |                                                 |                                           |                                                |                                                                        |
| BPT                                | 142                                             | 9.1                                       | 1510                                           | 1.0                                                                    |
| BAT                                | 166                                             | 1.7                                       | 4430                                           | 0.3                                                                    |
| BAT - BPT<br>(Incremental Control) | 24                                              | 0.3                                       | 2920                                           | 0.4                                                                    |

a/ Weighting factor equals 100. See text for derivation.

b/ Adjusted to omit cost of pH control.

c/ Too small to be considered significant. Figures in this row presented for completeness.

d/ BPT and BAT requirements are identical for this segment.



## EXHIBIT 3-25

ESTIMATES OF HAZARD SCALED COST-EFFECTIVENESS OF BPT AND BAT  
ASBESTOS REMOVAL

| Industry Segment<br>(1)            | Total "Hazard Units" Removed<br>(2) | Total Compliance Cost (1000 of 1980 \$)<br>(3) | Cost Per Hazard Unit Removed<br>(2)÷(3), (1000 of 1980 \$)<br>(4) |
|------------------------------------|-------------------------------------|------------------------------------------------|-------------------------------------------------------------------|
| Asbestos-Cement Pipe               |                                     |                                                |                                                                   |
| BPT                                | 410                                 | <sup>a/</sup> 440                              | 1.1                                                               |
| BAT                                | 700                                 | 1200                                           | 1.7                                                               |
| BAT - BPT<br>(Incremental Control) | 290                                 | 760                                            | 2.6                                                               |
| Asbestos-Cement Sheet              |                                     |                                                |                                                                   |
| BPT                                | 1675                                | <sup>a/</sup> 520                              | 0.3                                                               |
| BAT                                | 5875                                | 2000                                           | 0.3                                                               |
| BAT - BPT<br>(Incremental Control) | 4200                                | 1480                                           | 0.3                                                               |
| Asbestos Paper                     |                                     |                                                |                                                                   |
| BPT                                | 11,100                              | 320                                            | 0.03                                                              |
| BAT                                | 17,300                              | 1000                                           | 0.06                                                              |
| BAT - BPT<br>(Incremental Control) | 6,200                               | 680                                            | 0.11                                                              |

Continued on next page.

## EXHIBIT 3-25

ESTIMATES OF HAZARD SCALED COST-EFFECTIVENESS OF BPT AND BAT  
 ASBESTOS REMOVAL  
 (continued)

| Industry Segment<br>(1)            | Total "Hazard Units" Removed<br>(2) | Total Compliance Cost (1000 of 1980 \$)<br>(3) | Cost Per Hazard Unit Removed<br>(2)÷(3), (1000 of 1980 \$)<br>(4) |
|------------------------------------|-------------------------------------|------------------------------------------------|-------------------------------------------------------------------|
| Asbestos Millboard                 |                                     |                                                |                                                                   |
| BPT/BAT <sup>b/</sup>              | 2420                                | 230                                            | 0.1                                                               |
| Total                              |                                     |                                                |                                                                   |
| BPT                                | 15,605                              | 1510                                           | 0.1                                                               |
| BAT                                | 26,259                              | 4430                                           | 0.2                                                               |
| BAT - BPT<br>(Incremental Control) | 10,654                              | 2920                                           | 0.3                                                               |

a/ Adjusted to omit cost of pH control.

b/ BPT and BAT requirements are identical for this segment.

Although the relative hazard ratings used here are entirely speculative, the importance of appropriately considering the "hazardousness" of the substances being controlled is highlighted in this example. Using the hazard scaled results alters the relative cost-effectiveness among the industry segments; Millboard moves ahead of Cement Sheet and Pipe. Ignoring the hazardousness of substances being controlled could result in an inefficient allocation of resources among potential opportunities for reducing the total hazard presented by effluents.

Also important to note in the interpretation of the apportioned control costs is that the control costs per ton or per hazard unit do not represent real control opportunities. For example, if control costs for BAT in the asbestos-cement pipe industry is listed in Exhibit 3-24 as \$2,400 per ton of asbestos removed, one cannot prevent a ton of asbestos emissions for \$2,400. Instead, \$1.2 million must be spent, for which 500 tons of solids are controlled, of which approximately two tons are asbestos. Therefore, total compliance cost or cost per unit hazard is as important to examine as the cost per ton of asbestos removed in the evaluation of the alternative control opportunities.

#### 4. BENZENE

##### 4.1 INTRODUCTION

This chapter reviews three proposed regulations that would affect the rate and manner in which benzene is discharged into the environment. The three National Emission Standards for Hazardous Air Pollutants (NESHAPs) proposed under the authority of Section 112 of the Clean Air Act are:

- Benzene Emissions From Maleic Anhydride Plants;<sup>1</sup>
- Benzene Emissions From Ethylbenzene/Styrene Plants;<sup>2</sup> and
- Benzene Emissions From Benzene Storage Vessels.<sup>3</sup>

The purpose of these proposed rules is to prevent benzene air emissions from three categories of stationary sources, maleic anhydride plants, ethylbenzene/styrene plants, and benzene storage vessels, which may account for over fifty percent of total benzene emissions from stationary sources.<sup>4</sup> Other major sources include petroleum refineries, coke oven by-product plants, gasoline distribution, and gasoline marketing. EPA is also in the process of developing standards to cover some of these sources.<sup>5</sup>

The information in this chapter comes primarily from three documents prepared by EPA in support of the proposed rules:

- Benzene Emissions from Maleic Anhydride Industry-Background Information for Proposed Standards (Maleic Anhydride Support Document);<sup>6</sup>

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<sup>1</sup>45 FR 26660, April 18, 1980.

<sup>2</sup>45 FR 83448, December 18, 1980.

<sup>3</sup>45 FR 83952, December 19, 1980. A fourth regulation has been proposed to cover fugitive benzene emissions, 46 FR 1165, June 5, 1981.

<sup>4</sup>Benzene emissions from mobile sources may equal or exceed those from stationary sources. Therefore, the proposed regulations may apply to less than twenty-five percent of total air emissions of benzene.

<sup>5</sup>BNA, Chemical Regulation Reporter (Washington, D.C.: April 25, 1980), p. 105.

<sup>6</sup>EPA, Benzene Emissions from Maleic Anhydride Industry-Background Information for Proposed Standards (RTP, N.C.: February 1980 [EPA-450/3-80-001a]).



- Benzene Emissions from Ethylbenzene/Styrene Industry-Background Information for Proposed Standards (EB/S Support Document);<sup>7</sup> and
- Benzene Emissions from Benzene Storage Tanks-Background Information for Proposed Standards (Storage Tanks Support Document).<sup>8</sup>

The results of the economic and environmental impact analyses presented in these reports are summarized below.

These reports represent the most recent data published on the proposed benzene rules; however, EPA has received comments on the proposals which add important new information to the rulemaking process that is not reflected in these reports. In consideration of the additional data, EPA is currently developing regulatory options that are expected to be less costly per unit of emission reduction than the options presented in the above reports and analyzed here.<sup>9</sup> Therefore, the cost-effectiveness analyses of the benzene control options presented in this chapter do not include the most recent agency thinking, and are valuable primarily for their demonstrated application of cost-effectiveness analysis; as opposed to the identification and evaluation of potential EPA benzene control actions.

Using the reports cited above as the primary source of information, we examined two measures of effectiveness of the proposed regulations: metric tons of benzene emissions prevented annually; and reductions in the number of benzene-induced leukemias. This enabled us to compare the extent to which the cost-effectiveness measure of dollars-per-ton of emissions prevented reflects the cost-effectiveness of the proposals in terms of the health effects prevented.

Control Options. EPA examined technology based emission control alternatives for the three source categories mentioned above. Each technology is identified by an emission-reduction efficiency (e.g., 97 percent) that is based on the effectiveness of the technology for reducing emissions from an uncontrolled plant or storage tank. Because some plants and tanks currently have some emission controls, the emission-reduction percentages used to

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<sup>7</sup>EPA, Benzene Emissions from Ethylbenzene/Styrene Industry-Background Information for Proposed Standards (RTP, N.C.: August 1980 [EPA-450/3-79-035a]).

<sup>8</sup>EPA, Benzene Emissions from Benzene Storage Tanks-Background Information for Proposed Standards (RTP, N.C.: December 1980 [EPA-450/3-80-034a]).

<sup>9</sup>Personnel communication with Susan Wyatt, OAQPS, EPA (December 3, 1981). The new regulatory options under consideration are not as yet published.

identify the control options do not indicate the percentage reduction achievable from current emissions. The percentages of emissions reduction achievable under the various options relative to current levels of emissions were estimated based on current control practices and are actually less than the percentages identifying the control options. The proposed control options can be summarized as follows:

- Maleic Anhydride Industry:<sup>10</sup>

Option 1--Benzene control efficiency of 97 percent, which can be achieved by carbon adsorption or thermal incineration.

Option 2--Benzene control efficiency of 99 percent, which can be achieved by either thermal incineration or carbon adsorption.

Option 3--Benzene control efficiency of 100 percent, which can only be achieved by new sources by substituting n-butane as a feedstock (does not apply to existing sources).

- Ethylbenzene/Styrene Industry:<sup>11</sup>

Option 1--Continuous benzene emissions reduced by 85 percent, based on the use of scrubbers and condensers.

Option 2--Continuous benzene emissions reduced by 94 percent, based on the use of a flare system coupled to scrubbers and condensers.

Option 3--Continuous benzene emissions reduced by 99 percent, based on the use of a boiler (including process heaters and superheaters).

- Benzene Storage Tanks:<sup>12</sup> five technological control options for retrofitting existing tanks and four technological control options for new benzene storage tanks were investigated.

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<sup>10</sup>EPA, Benzene Emissions from Maleic Anhydride Industry-Background Information for Proposed Standards, op. cit., pp. 3-1 through 3-2.

<sup>11</sup>EPA, Benzene Emissions from Ethylbenzene/Styrene Industry-Background Information for Proposed Standards, op. cit., p. 1-1.

<sup>12</sup>EPA, Benzene Emissions from Benzene Storage Tanks-Background Information for Proposed Standards, op. cit., pp. 1-2, 1-3.

Additionally, EPA examined emission reduction requirements for excess benzene emissions from the EB/S and maleic anhydride industries. These emissions occur during plant start-up, shut-down, and malfunctions.<sup>13</sup> These requirements are not examined here.

The remainder of this chapter summarizes the estimated economic and environmental impacts of these various control options, and examines the relationship between effectiveness measures in terms of tons of emissions prevented annually, and health benefits. As mentioned above, and as we emphasize here, EPA is currently developing additional control options that are based, in part, on information not available for this chapter.

#### 4.2 BENZENE NESHAP COST ANALYSIS

Compliance costs for each source category were estimated separately. However, some general observations are in order. Compliance costs are based on the extrapolation of estimated "model plant compliance costs" to the individual source categories. Model plants were developed to represent the typical process configuration or storage facility, and detailed cost estimates were performed for each. In the maleic anhydride and EB/S industries the model plant estimates were used to estimate compliance costs, current emission levels, and potential emission reductions at each individual plant. The primary considerations in the extrapolation of costs were current control practices and the size of the plant. The inability to include other process parameters for consideration may affect the accuracy of the cost estimates. The extent of these errors and their potential bias are not known. Regression analysis was used to extrapolate costs to the existing population of benzene storage tanks. The accuracy of the extrapolation is not reported.

All compliance costs estimated by EPA include capital costs, operation and maintenance costs, insurance, property taxes, and credits for recovered benzene. There was no discussion of investment tax credits or income tax effects so we assume that the figures quoted represent pre-tax private costs of compliance. Assuming there are no significant indirect effects of compliance (e.g., price effects, reduced employment, balance of trade), these compliance cost estimates are taken to be representative of total social costs of compliance.<sup>14</sup>

EPA's cost estimates for each source category are summarized below.

##### 4.2.1 Maleic Anhydride Industry

Maleic anhydride is an important raw material in the production of resins, lubricants and agricultural chemicals. In 1977, the industry

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<sup>13</sup>EPA, Benzene Emissions from Ethylbenzene/Styrene Industry-Background Information for Proposed Standards, op. cit., p. 1-2.

<sup>14</sup>Property taxes should not be included. However, they are very small and their effect here is considered negligible.

consisted of ten plants, eight of which used benzene as a feedstock and would be affected by the proposed standards, and two of which used n-butane. (Conversion from benzene to n-butane may not be economical for all existing plants, but new plants can economically use either benzene or n-butane.) The industry has changed substantially since 1977.<sup>15</sup> The extent to which the proposed regulations were a factor influencing the changes in the industry was not investigated in the preparation of this analysis. The analysis that follows is based on the condition of the industry that existed when the original EPA proposals were analyzed.

The standards originally proposed for new and existing plants were developed from options requiring 97 percent and 99 percent control of benzene emissions. For new plants, the use of n-butane as opposed to benzene is an additional regulatory option.

The baseline against which control costs were measured was current practices. Plants with a 99 percent control level prior to regulation were assumed to require no additional controls. Those that controlled between 97 and 99 percent of emissions were assumed to need no additional controls for the 97 percent alternative, and the necessary incremental control was identified to estimate costs under the 99 percent alternative.

EPA estimated costs for both the 97 and 99 percent alternatives for the eight existing plants producing maleic anhydride from benzene. Costs were not assigned to new facilities because only one new plant is currently planned, and that is expected to use n-butane. Compliance cost estimates for existing plants were derived by EPA as a function of production capacity and current level of control. Other differences, such as production process or condition of equipment, across the existing plants were not considered. EPA assumed each plant to have the technical parameters shown in Exhibit 4-1.

It was assumed that the necessary incinerators or carbon adsorption units would be retrofitted. An incinerator was estimated to cost 40 percent more as a retrofit than it would as a new installation, and a carbon adsorption unit was estimated to cost 30 percent more than it would new.

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<sup>15</sup>The status of the maleic anhydride industry has changed since the control options were initially analyzed. Koppers shut down its Bridgeville, PA, plant in March 1979 and currently has no plans to reactivate it for maleic anhydride production. Reichhold shut down its Elizabeth, NJ, plant in August 1979. The Monsanto St. Louis Plant has begun to install a thermal incinerator that can achieve 97 percent control of benzene emissions. This Monsanto Plant is the single largest source of uncontrolled benzene emissions, and the adoption of this technology (which is expected soon) will significantly reduce the level of emissions that could be potentially controlled by this proposed regulation. The Tenneco New Jersey Plant is being required by the State of New Jersey to reduce its benzene emissions by 99 percent (or, if it switches to n-butane to control 97 percent of potential n-butane emissions). Also on an experimental basis, DENKA and Ashland are converting all or part of their production to use n-butane as feedstock. This information comes from the OAQPS, EPA rulemaking docket for this proposed regulation.



## EXHIBIT 4-1

ESTIMATED TECHNICAL PARAMETERS USED IN  
DEVELOPING CONTROL SYSTEM COSTS

| <u>Parameter</u>                                            | <u>Value a/</u>                                                          |
|-------------------------------------------------------------|--------------------------------------------------------------------------|
| 1. Gas temperature                                          | 38° C (100° F)                                                           |
| 2. Gas pressure                                             | 120 KPa (18 psia)                                                        |
| 3. Gas volumetric flow rate                                 | 0.0536 P m <sup>3</sup> /min (1.89 P ACFM) b/                            |
| 4. Inlet benzene emission rate                              | 0.0084 P kg/hr (0.0185 P lb/hr) b/                                       |
| 5. Benzene control efficiency                               | 97%, 99%                                                                 |
| 6. Plant capacities                                         | Actual capacities                                                        |
| 7. Incinerator combustion<br>temperature and residence time | 760° C (1,400° F), 0.5 sec for 97%<br>870° C (1,600° F), 0.5 sec for 99% |
| 8. Design carbon loading                                    | 6 kg VOC/100 kg carbon (6 lb VOC/<br>100 lb carbon)                      |

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a/ EPA estimates.

b/ P = plant capacity in megagrams of maleic anhydride per year.

Sources: Lawson, J. F., Emission Control Options for the Synthetic Organic Chemicals Manufacturing Industry Maleic Anhydride--Product Report. Hydrosience, Inc. (prepared for Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, N.C.) EPA Contract Number 68-02-2577, March 1978.

Letter from Vatavuk, William M., Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, to Weber, Robert, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, March 28, 1978.



Capital costs included purchase, site preparation, and installation. Total annualized costs also included operation and maintenance costs (including labor, materials, and utilities) and capital charges including depreciation, interest, insurance and property taxes. Compliance costs were estimated to be partially offset by recovery credits for benzene recovered in control devices. The cost offsets are reflected in the annualized cost estimates. A real interest rate of 10 percent and an equipment life of 10 years were assumed. Administrative costs, taxes and insurance were set at 4 percent of the installed capital cost. Exhibit 4-2 summarizes EPA's compliance cost estimates for each of the maleic anhydride plants.

It should be noted that the range of cost estimates corresponds to two assumptions of capacity utilization: 100 percent utilization (8,000 hours per year); and 56 percent utilization (4,500 hours per year). The range is caused by differences in operation and maintenance costs and benzene recovery credits. At the time of the report, plants were operating at less than full capacity. Investors are reportedly confident that plants will achieve 100 percent capacity utilization by the end of 1982, though excess capacity has been common in the maleic anhydride industry. In order to account for changes in capacity utilization, costs (and emissions) should reflect the expected growth in production over the duration of the standard.

The cost estimates in Exhibit 4-2 do not include costs to users of maleic anhydride and costs borne in the markets for substitutes and complements. These costs were estimated by EPA and found to be small.

Intermedia effects and credits for reducing emission of volatile organic compounds (VOCs) are also not included in these cost estimates. For example, with carbon adsorption, 44 tons per year of benzene and 467 tons of other VOCs would be diverted from air emissions to water. Thus, the controls have an additional cost--the cost of controlling these emissions in water (or the health cost of their release). Similarly, nitrogen oxides ( $\text{NO}_x$ ) are released to air in incineration and should be classified among costs as should sulfur dioxide ( $\text{SO}_2$ ) released in oil based incineration. The omission of these intermedia effects understates the total social costs of control.

On the other hand, controls were not given credit for the other hazardous chemicals that would be controlled along with benzene. Total costs should actually be reduced or benefits increased to reflect emission reductions in other chemicals being controlled. For example, carbon monoxide (CO) emissions are reduced in incineration involving natural gas. In the model uncontrolled plant, the emission stream was comprised of 78 percent benzene by weight and 22 percent of other VOCs. If controls are equally efficient in controlling VOCs and benzene, this would mean only 78 percent of the total emissions reduction in VOCs was taken into account in measuring benefits. This will be discussed further in the section on emission reduction estimates.

Primary sources of uncertainty in the cost estimates in Exhibit 4-2 are the following:

- It is unclear how variations in the characteristics assumed to be identical across plants actually affect costs. EPA estimates 30 percent error.

## EXHIBIT 4-2

SUMMARY OF EPA ESTIMATES OF COMPLIANCE COSTS  
FOR THE MALEIC ANHYDRIDE INDUSTRY  
(Existing plants only)

| Plant                                       | OPTION I                                                             |                                                | OPTION II                                                            |                                                |
|---------------------------------------------|----------------------------------------------------------------------|------------------------------------------------|----------------------------------------------------------------------|------------------------------------------------|
|                                             | 27 Percent Benzene Emission Reduction<br>(Thousands of 1980 Dollars) | Annualized Cost<br>(Thousands of 1980 Dollars) | 29 Percent Benzene Emission Reduction<br>(Thousands of 1980 Dollars) | Annualized Cost<br>(Thousands of 1980 Dollars) |
|                                             | Carbon Adsorption a/                                                 | Incineration b/                                | Carbon Adsorption a/                                                 | Incineration b/                                |
| 1. Ashland--Neal, West Virginia             | 430-450                                                              | 450-520                                        | 450-460                                                              | 585-730                                        |
| 2. Monsanto--St. Louis, Missouri            | 570-600                                                              | 600-700                                        | 585-610                                                              | 785-990                                        |
| 3. DENKA--Houston, Texas                    | 0                                                                    | 0                                              | 390-400                                                              | 500-630                                        |
| 4. Reichhold--Elizabeth, New Jersey         | 0                                                                    | 0                                              | 255-265                                                              | 340-420                                        |
| 5. Reichhold--Morris, Illinois              | 335-350                                                              | 350-420                                        | 345-360                                                              | 460-570                                        |
| 6. Tenneco--Fords, New Jersey               | 220-230                                                              | 230-290                                        | 235-240                                                              | 310-380                                        |
| 7. U.S. Steel--Neville Island, Pennsylvania | 570-600                                                              | 610-700                                        | 590-615                                                              | 790-1,000                                      |
| 8. Koppers--Bridgeville, Pennsylvania       | 0                                                                    | 0                                              | 0                                                                    | 0                                              |
| TOTAL                                       | 2,215-2,230                                                          | 2,240-2,630                                    | 2,850-2,950                                                          | 3,770-4,720                                    |

a/ Cost range represents varying the assumption regarding the capacity utilization of the plant. The low figure represents 100 percent capacity utilization (8,000 hr./yr.) which is expected by 1983. The higher figure represents 56 percent capacity utilization (4,500 hr./yr.) which was the case in 1977. Costs are reduced with higher capacity utilization because more benzene is recovered.

b/ Cost range represents varying the assumption regarding the capacity utilization of the plant. The low figure represents 56 percent capacity utilization (4,500 hr./yr.) which was the case in 1977. The high figure represents 100 percent capacity utilization (8,000 hr./yr.) which is expected by 1983.

Source: EPA, Benzene Emissions from Maleic Anhydride Industry-Background Information for Proposed Standards (RTP, N.C.; February 1980 [EPA-450/3-80-001a]), pp. 5-21 through 5-24. Figures displayed here are adjusted for inflation using the implicit GNP deflator.

- There is uncertainty regarding the appropriate capital recovery factor, given the age of existing equipment in the plant. We cannot estimate the error introduced because there is inadequate information about individual plants.
- Costs do not incorporate effects on related industries which use or substitute for benzene or maleic anhydride and in particular how their toxic emissions are effected.
- Costs which may be imposed in the future if the maleic anhydride industry increases its capacity are not included.
- Increased emissions in wastewater and increased or reduced emissions of other toxic substances as a result of the control options are not incorporated in these costs.

#### 4.2.2 Ethylbenzene/Styrene Industry

Ethylbenzene and styrene are considered a single industry because 99 percent of all ethylbenzene is used in styrene production and styrene is produced only from ethylbenzene. Ten plants produce both ethylbenzene and styrene, five plants produce only ethylbenzene, and two produce only styrenes. These seventeen plants are owned by fourteen different companies, and are listed in Exhibit 4-3.

Styrenes are used almost entirely in polymer manufacture and in particular in the production of plastic and rubber. Virtually all of the plants in the ethylbenzene industry are in Texas and Louisiana. While the market is fairly concentrated, firms face competition from foreign sources. The firms comprising the industry are highly diversified in the products they produce, so that high control costs could in theory cause them to shift resources from ethylbenzene/styrene to their other activities. In recent years, production has been growing at a rate of about 8 to 11 percent per year.

The industry was assumed to be in compliance with existing regulations prior to adoption of proposed standards. Available data for existing plants were used to estimate existing levels of control and emissions from the primary sources of emissions, the main process area vents. The five plants using only the mixed xylene stream recovery process were found to emit no benzene and did not require controls<sup>16</sup> (see Exhibit 4-3). The remaining twelve plants with benzene emissions were examined and the existing controls and baseline emissions were estimated for each plant in the industry.

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<sup>16</sup>EPA, Benzene Emissions from Ethylbenzene/Styrene Industry-Background Information for Proposed Standards op. cit., p. 3-25.

EXHIBIT 4-3  
U.S. ETHYLBENZENE/STYRENE CAPACITIES a/

| Company                                                      | Ethylbenzene                                      |                                               | Process | Styrene                                                       |         |
|--------------------------------------------------------------|---------------------------------------------------|-----------------------------------------------|---------|---------------------------------------------------------------|---------|
|                                                              | <sup>3</sup><br>(10 <sup>3</sup> metric tons/yr.) | Capacity<br>(10 <sup>3</sup> metric tons/yr.) |         | <sup>3</sup><br>Capacity<br>(10 <sup>3</sup> metric tons/yr.) | Process |
| American Hoechst Corp.<br>Baton, Rouge, Louisiana b/         |                                                   | 526                                           | c       | 450                                                           | e       |
| Amoco<br>Texas City, Texas                                   |                                                   | 447                                           | c       | 380                                                           | e       |
| Atlantic Richfield Co.<br>Port Arthur, Texas                 |                                                   | 227                                           | c       |                                                               |         |
| Atlantic Richfield Co.<br>Kobuta, Pennsylvania               |                                                   |                                               |         | 200                                                           | e       |
| Charter<br>Houston, Texas                                    |                                                   | 18                                            | d       |                                                               |         |
| Commonwealth Oil Refining Co., Inc.<br>Penuelas, Puerto Rico |                                                   | 73                                            | d       |                                                               |         |
| Cos-Mar<br>Caville, Louisiana                                |                                                   | 689                                           | c       | 590                                                           | e       |
| Dow Chemical U.S.A.<br>Freeport, Texas                       |                                                   | 847                                           | c       | 680                                                           | e       |
| Dow Chemical U.S.A.<br>Midland, Michigan                     |                                                   |                                               |         | 181                                                           | e       |
| El Paso Products Co.<br>Odessa, Texas                        |                                                   | 125                                           | c       | 115                                                           | e       |
| Gulf Oil Corp.<br>Donaldville, Louisiana                     |                                                   | 313                                           | c       | 272                                                           | e       |
| Monsanto Company<br>Alvin, Texas                             |                                                   | 23                                            | d       |                                                               |         |
| Monsanto Company<br>Texas City, Texas                        |                                                   | 771                                           | c,d     | 680                                                           | e       |

EXHIBIT 4-3 (continued)  
U.S. ETHYLBENZENE/STYRENE CAPACITIES <sup>a/</sup>

| Company                              | Ethylbenzene                                                  |         | Styrene                                                       |         |
|--------------------------------------|---------------------------------------------------------------|---------|---------------------------------------------------------------|---------|
|                                      | <sup>3</sup><br>Capacity<br>(10 <sup>3</sup> metric tons/yr.) | Process | <sup>3</sup><br>Capacity<br>(10 <sup>3</sup> metric tons/yr.) | Process |
| Oxirane<br>Channelview, Texas        | 545                                                           | c       | 454                                                           | f       |
| Sun Oil Co.<br>Corpus Christi, Texas | 61                                                            | c,d     | 36                                                            | e       |
| Tenneco<br>Chalmette, Louisiana      | 16                                                            | d       |                                                               |         |
| U.S. Steel<br>Houston, Texas         | <u>61</u>                                                     | d       | <u>54</u>                                                     | e       |
| TOTAL                                | 4,742                                                         | .       | 4,092                                                         |         |

<sup>a/</sup> Industry status as of 1978.

<sup>b/</sup> American Hoechst Corp. plans to bring a  $408.2 \times 10^3$  metric tons/yr. styrene plant on-stream at Bayport, Texas in 1980.

<sup>c/</sup> Benzene alkylation.

<sup>d/</sup> Mixed xylene stream recovery, does not emit benzene.

<sup>e/</sup> Ethylbenzene dehydrogenation.

<sup>f/</sup> Ethylbenzene hydroperoxidation.

Source: EPA, Benzene Emissions from Ethylbenzene/Styrene Industry-Background Information for Proposed Standards (RIP, N.C.: August 1980 [EPA-450/3-79-035a]), p. 3-3.



EPA estimated industry-wide compliance costs by developing cost and emissions estimates for a model uncontrolled plant and extrapolating to each plant in the industry. The model plant was developed on the basis of EPA field surveys, tests, and literature searches. The extrapolation of costs and emissions from the model plant to individual plants assumed that each plant has the same physical characteristics as the model plant with the exception of plant capacity. The actual control levels of the existing plants were used to adjust the estimates as required. It is not known if any bias is introduced by these assumptions.

Emissions or "vent flows" were assumed to be related linearly to plant capacity, however, vent flows actually vary with throughput rather than capacity. When the ethylbenzene and styrene plants reach full capacity utilization (expected by the end of 1982), this assumption will be correct. At the time of the report, the industries were operating at 70 percent and 78 percent capacity utilization respectively, and the estimated vent emissions overstate actual emissions.

The control technologies plants would install are scrubbers, condensers, flare systems, boilers, and related equipment, depending upon the regulatory option. Exhibit 4-4 describes the equipment each plant would require in order to comply with control Options 1, 2, and 3.<sup>17</sup>

Total annualized cost estimates include operating and maintenance costs, annualized capital costs, fuel costs, credits for benzene recovery, overhead and contingencies. It was assumed that all benzene removed by the scrubber/condenser system was eligible for the benzene recovery credit. These material recovery credits reduced compliance costs significantly, and in many cases result in cost savings to individual plants.

EPA's cost estimates inflated to 1980 dollars are as follows:

- Option 1--85 percent control: savings of \$715 thousand.
- Option 2--94 percent control: savings of \$245 thousand.
- Option 3--99 percent control: savings of \$541 thousand.

The predicted result that the controls would result in cost savings is somewhat curious because one may question why firms have not voluntarily undertaken these controls. However, the costs estimated here represent total social costs (savings) and do not necessarily represent private after-tax costs (savings) to individual firms. Additionally, most of the cost savings realized from product recovery are estimated to be accounted for by two plants, Cos-Mar and Oxirane (see Exhibit 4-5). Most of the plants have at least one control option with positive costs.

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<sup>17</sup>As mentioned above, EPA is currently considering additional control options.

EXHIBIT 4-4  
PLANT-BY-PLANT LIST OF EQUIPMENT NEEDED TO ACHIEVE GIVEN REGULATORY OPTIONS

| Plant                 | Regulatory Option | Control Equipment |                 |                    |          |           |                |                 | Oxygen | Scrubber |
|-----------------------|-------------------|-------------------|-----------------|--------------------|----------|-----------|----------------|-----------------|--------|----------|
|                       |                   | Partial Header    | Complete Header | Incremental Header | 3" Flare | 10" Flare | Partial Burner | Complete Burner |        |          |
| Arco, Texas           | 85                |                   |                 |                    |          |           |                |                 |        |          |
| Arco, Texas           | 94 Flare          |                   | X               |                    | X        |           |                |                 | X      | X        |
| Arco, Texas           | 99 Boiler         |                   | X               |                    |          |           |                |                 | X      |          |
| American Hoechst      | 85                |                   |                 |                    |          |           |                |                 |        |          |
| American Hoechst      | 94 Flare          |                   | X               |                    | X        |           |                |                 | X      | X        |
| American Hoechst      | 99 Boiler         |                   | X               |                    |          |           |                |                 | X      |          |
| Cos-mar, Louisiana    | 85                |                   |                 |                    |          |           |                |                 |        |          |
| Cos-mar, Louisiana    | 94 Flare          | X                 |                 |                    | X        |           |                |                 | X      | X        |
| Cos-mar, Louisiana    | 99 Boiler         | X                 |                 |                    |          |           |                |                 | X      |          |
| Gulf Chemicals, Texas | 85                |                   |                 |                    |          |           |                |                 |        |          |
| Gulf Chemicals, Texas | 94 Flare          | X                 |                 |                    | X        |           |                |                 | X      | X        |
| Gulf Chemicals, Texas | 99 Boiler         | X                 |                 |                    |          |           |                |                 |        |          |
| Monsanto              | 85                |                   |                 |                    |          |           |                |                 |        |          |
| Monsanto              | 94 Flare          |                   | X               |                    | X        |           |                |                 |        | X        |
| Monsanto              | 99 Boiler         |                   | X               |                    |          |           |                |                 |        | X        |
| Amoco, Texas          | 85                |                   |                 |                    |          |           |                |                 |        |          |
| Amoco, Texas          | 94 Flare          | X                 |                 |                    | X        |           |                |                 | X      | X        |
| Amoco, Texas          | 99 Boiler         | X                 |                 |                    |          |           |                |                 | X      |          |
| Dow, Texas            | 85                |                   |                 |                    |          |           |                |                 |        |          |
| Dow, Texas            | 94 Flare          | X                 |                 |                    | X        |           |                |                 | X      | X        |
| Dow, Texas            | 99 Boiler         | X                 |                 |                    |          |           |                |                 | X      |          |
| Dow, Texas            | Compressor        |                   |                 | X                  |          | X         |                |                 |        |          |
| Sun Oil, Texas        | 85                |                   |                 |                    |          |           |                |                 |        |          |
| Sun Oil, Texas        | 94 Flare          | X                 |                 |                    | X        |           |                |                 | X      | X        |
| Sun Oil, Texas        | 99 Boiler         | X                 |                 |                    |          |           |                |                 | X      |          |
| Sun Oil, Texas        | Compressor        |                   |                 | X                  |          |           |                |                 |        |          |
| El Paso, Texas        | 85                |                   |                 |                    |          |           |                |                 |        |          |
| El Paso, Texas        | 94 Flare          |                   |                 |                    |          |           |                |                 |        |          |
| El Paso, Texas        | 99 Boiler         | X                 |                 |                    | X        |           |                |                 | X      | X        |
| Oxirane               | 85                |                   |                 |                    |          |           |                |                 |        |          |
| Oxirane               | 94 Flare          |                   |                 |                    |          |           |                |                 |        | X        |
| Oxirane               | 99 Boiler         | X                 |                 |                    |          |           |                |                 | X      |          |

EXHIBIT 4-4 (continued)  
PLANT-BY-PLANT LIST OF EQUIPMENT NEEDED TO ACHIEVE GIVEN REGULATORY OPTIONS

| Plant                                                          | Regulatory Option           | Control Equipment |                 |                    |          |           |                |                 | Scrubber |
|----------------------------------------------------------------|-----------------------------|-------------------|-----------------|--------------------|----------|-----------|----------------|-----------------|----------|
|                                                                |                             | Partial Header    | Complete Header | Incremental Header | 3" Flare | 10" Flare | Partial Burner | Complete Burner |          |
| Arco, Pennsylvania<br>Arco, Pennsylvania<br>Arco, Pennsylvania | 85<br>94 Flare<br>99 Boiler |                   |                 |                    |          |           |                |                 |          |
|                                                                |                             | X                 |                 |                    | X        |           |                | X               | X        |
|                                                                |                             | X                 |                 |                    |          |           | X              | X               | X        |
| Dow, Michigan<br>(Styrene Only)                                | 85<br>94 Flare<br>99 Boiler | X                 |                 |                    | X        |           |                | X               | X        |
|                                                                |                             | X                 |                 |                    |          |           | X              | X               | X        |

Source: EPA, Benzene Emissions from Ethylbenzene/Styrene Industry-Background Information for Proposed Standards (RTP, N.C.: February 1980 [EPA-450/3-79-035a]), p. 7-38.

## EXHIBIT 4-5

EPA ESTIMATES OF PLANT-BY-PLANT COSTS  
FOR THE ETHYLBENZENE/STYRENE INDUSTRY

| <u>Plant</u>       | <u>Option<br/>(percent<br/>emission<br/>reduction)</u> | <u>Capital Cost<br/>(thousands of<br/>1978 dollars)</u> | <u>Annualized<br/>Cost (Savings) <sup>a/</sup><br/>(thousands of<br/>1978 dollars)</u> |
|--------------------|--------------------------------------------------------|---------------------------------------------------------|----------------------------------------------------------------------------------------|
| Arco               |                                                        |                                                         |                                                                                        |
| Port Arthur, Texas | 85                                                     | 121                                                     | (40)                                                                                   |
|                    | 94 Flare                                               | 290                                                     | 6.5                                                                                    |
|                    | 99 Boiler                                              | 235                                                     | (14)                                                                                   |
| American Hoechst   | 85                                                     | 164                                                     | (46)                                                                                   |
| Louisiana          | 94 Flare                                               | 316                                                     | (45)                                                                                   |
|                    | 99 Boiler                                              | 421                                                     | (72)                                                                                   |
| Cos-Mar            |                                                        |                                                         |                                                                                        |
| Louisiana          | 85                                                     | 268                                                     | (167.5)                                                                                |
|                    | 94 Flare                                               | 530                                                     | (96)                                                                                   |
|                    | 99 Boiler                                              | 448                                                     | (147)                                                                                  |
| Gulf Chemicals     |                                                        |                                                         |                                                                                        |
| Texas              | 85                                                     | 130                                                     | (75)                                                                                   |
|                    | 94 Flare                                               | 258                                                     | (40)                                                                                   |
|                    | 99 Boiler                                              | 215                                                     | (64.5)                                                                                 |
| Monsanto           | 85                                                     | 66                                                      | (32)                                                                                   |
| Texas              | 94 Flare                                               | 325                                                     | 39                                                                                     |
|                    | 99 Boiler                                              | 424                                                     | (76.5)                                                                                 |
| Amoco              | 85                                                     | 72                                                      | (28)                                                                                   |
| Texas              | 94 Flare                                               | 213                                                     | 13                                                                                     |
|                    | 99 Boiler                                              | 200                                                     | 7                                                                                      |
| Dow                |                                                        |                                                         |                                                                                        |
| Texas              | 85                                                     | 142                                                     | (78)                                                                                   |
|                    | 94 Flare                                               | 387                                                     | (28)                                                                                   |
|                    | 99 Boiler                                              | 555                                                     | (75)                                                                                   |
| Sun Oil            |                                                        |                                                         |                                                                                        |
| Texas              | 85                                                     | 66                                                      | 13.5                                                                                   |
|                    | 94 Flare                                               | 173                                                     | 45                                                                                     |
|                    | 99 Boiler                                              | 130                                                     | 23                                                                                     |

## EXHIBIT 4-5 (continued)

EPA ESTIMATES OF PLANT-BY-PLANT COSTS  
FOR THE ETHYLBENZENE/STYRENE INDUSTRY

| <u>Plant and Location</u> | <u>Option<br/>(percent<br/>emission<br/>reduction)</u> | <u>Capital Cost<br/>(thousands of<br/>1978 dollars)</u> | <u>Annualized <sup>a</sup>/<br/>Cost (Savings)<br/>1978 dollars)</u> |
|---------------------------|--------------------------------------------------------|---------------------------------------------------------|----------------------------------------------------------------------|
| El Paso                   |                                                        |                                                         |                                                                      |
| Texas                     | 85                                                     | 33                                                      | 8.5                                                                  |
|                           | 94 Flare                                               | 33                                                      | 8                                                                    |
|                           | 99 Boiler                                              | 130                                                     | 26                                                                   |
| Oxirane                   | 85                                                     | 243                                                     | (172)                                                                |
| Texas                     | 94 Flare                                               | 243                                                     | (172)                                                                |
|                           | 99 Boiler                                              | 366                                                     | (119)                                                                |
| Arco                      |                                                        |                                                         |                                                                      |
| Pennsylvania              | 85                                                     | 74                                                      | 9.5                                                                  |
|                           | 94 Flare                                               | 180                                                     | 38                                                                   |
|                           | 99 Boiler                                              | 130                                                     | 27                                                                   |
| Dow                       |                                                        |                                                         |                                                                      |
| Midland                   | 85                                                     | 61                                                      | (1)                                                                  |
|                           | 94 Flare                                               | 173                                                     | 30                                                                   |
|                           | 99 Boiler                                              | 142                                                     | 25                                                                   |
| TOTAL                     | 85                                                     | 1,440                                                   | (608)                                                                |
|                           | 94 Flare                                               | 3,121                                                   | (201.5)                                                              |
|                           | 99 Boiler                                              | 3,396                                                   | (460)                                                                |

<sup>a</sup>/ Annualized costs include annualized capital changes, variable costs, and recovery credits.

Source: EPA, Benzene Emissions from Ethylbenzene/Styrene Industry-  
Background Information for Proposed Standards (RTP, N.C.:  
August 1980 [EPA-450/3-79-035a]), p. 7-40.



The cost savings are also very large because the price of styrene nearly tripled between 1973 and 1974.<sup>18</sup> This rapid shift in price, changes the least cost production method for producers. Therefore, many producers may reduce emissions even without promulgation of the standards. This possibility affects the accuracy of the baseline assumption of 1978 current practices used in EPA's analysis. The incremental effect of the proposed standards on industry costs and emissions may be smaller than reported.

Material credits for the recovery of other aromatics were not included because amounts were not estimated. This omission implies that costs are overstated but it is not known by how much. To make such an estimate, we must know whether or not the control devices remove other VOCs in the same proportion as they do benzene. Monitoring costs, such as the labor and equipment required to detect capital failures, were also omitted from the cost analysis. This omission may be justified, as monitoring of benzene emissions is not required. Exhibit 4-5 displays EPA's estimates for plants and total industry compliance costs.

EPA's cost estimates did not allow for changes in the volume of production at the plants or for structural changes in the industry. Instead, it was assumed that all plants would operate at full capacity. In fact, ethylbenzene and styrene plants were operating at 70 and 78 percent of capacity, respectively, at the time of the analysis. Demand for styrene was projected to increase by five percent annually until 1985. As a result, 1,200,000 to 1,300,000 metric tons of new capacity would be added, while 928,000 metric tons of older, less efficient capacity would be closed. The manner in which these changes affect costs depends upon several factors:

- the relationship between production changes and changes in variable costs;
- the relationship between production changes and changes in emissions (and thus the benzene and fuel recovery credits);
- the distribution of the shutdown of old and inefficient plants; and
- the distribution and manner (construction of new plants, additions to old plants) of capacity expansion.

Without knowing how variable costs change as production changes, or how producers will respond to the need for more capacity, we cannot quantitatively revise EPA's estimates to account for these factors. Therefore, the annualized costs (net of the recovery credits) represent an upper bound on

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<sup>18</sup>EPA, Emissions from Ethylbenzene/Styrene Industry-Background Information for Proposed Standards, op. cit., p. 7-12.

current costs, since capacity utilization is less than 100 percent. They represent a lower bound on annual costs after 1982, since total production is expected to increase beyond existing capacity. The net effect on total annualized costs is uncertain, because as production and variable costs rise, so do benzene emissions reductions and total benzene and fuel recovery credits. Therefore, the industry costs summarized in Exhibit 4-5 should be thought of as having limited applicability in the sense that they apply only to existing plants at 100 percent capacity.

Economic costs in the markets for substitutes and complements are not incorporated into these cost estimates. Apparently, there are no effective substitutes for ethylbenzene/styrene so that the omission of consideration of substitutes seems appropriate. "Credits" for controlling other aromatics are also omitted. Either the total cost should be allocated between benzene and the other controlled aromatics or the benefits of their control should be counted among benefits. We choose to use the second convention here. Intermedia effects are also expected to be negligible so that their omission from the cost analysis is appropriate.

#### 4.2.3 Benzene Storage Tanks

EPA originally proposed several control options for both new and existing benzene storage facilities. The regulations would pertain to all benzene storage facilities other than those at coke oven byproduct plants. The control options originally proposed are summarized in Exhibits 4-6 and 4-7.<sup>19</sup>

Benzene storage tanks are found at both large and small production facilities, at bulk storage facilities, and at benzene consumption facilities. Storage capacity is expected to grow at about 5 percent per year, however, the distribution of that growth between types of facilities is uncertain.

The industry was assumed to be in compliance with current standards. In particular, tanks built prior to May 18, 1978 were assumed to meet the EPA Control Techniques Guidelines of December 1977<sup>20</sup> and newer tanks (those built after May 18, 1978) were assumed to meet the New Source Performance Standard (NSPS) for petroleum liquid storage vessels.<sup>21</sup> Additionally, an industry survey provided data on actual controls at many existing plants. For plants for which actual data were available, current practices was the baseline and for other facilities current standards was the baseline.

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<sup>19</sup>EPA may develop additional control options.

<sup>20</sup>EPA, Control of Volatile Organic Emissions from Storage of Petroleum Liquids in Fixed Roof Tanks (Washington, D.C.: December 1977 [EPA-450/2-77-036]).

<sup>21</sup>45 FR 23374.

EXHIBIT 4-6

CONTROL OPTIONS FOR EXISTING BENZENE STORAGE TANKS

- Option 0--Baseline (no additional standard).
- Option 1--Each fixed-roof storage tank must be retrofitted with an internal floating roof (contact and noncontact).
- Option 2--Each fixed-roof storage tank must be retrofitted with an internal floating roof (contact or noncontact); each external floating-roof storage tank must be retrofitted with a secondary seal.
- Option 3--Each fixed-roof, external floating-roof, and internal floating-roof storage tank must be converted to a contact internal floating-roof storage tank with a liquid-mounted primary seal.
- Option 4--Each fixed roof, external floating-roof, and internal floating-roof storage tank must be converted to a contact internal floating-roof storage tank with a liquid-mounted primary seal and a continuous secondary seal.
- Option 5--Each fixed-roof, external floating roof, and internal floating-roof storage tank must be fitted to a vapor control system. Two vapor control systems which have been analyzed in detail include: a steam-regenerated carbon adsorption system; and a thermal oxidation system.
- Option 6--Prohibit the storage of benzene in tanks.

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Source: EPA, Benzene Emissions from Benzene Storage Tanks--Background Information for Proposed Standards (Research Triangle Park, North Carolina: December 1980 [EPA-450/3-80-034a]), p. 1-2.

EXHIBIT 4-7

CONTROL OPTIONS FOR NEW BENZENE STORAGE TANKS

- Option 0--Baseline (no additional standard).
- Option 1--Each fixed-roof storage tank must have an internal floating roof (contact and noncontact).
- Option 2--Each storage tank must have a contact internal floating-roof with a liquid-mounted primary seal.
- Option 3--Each storage tank must have a contact internal floating roof with a liquid-mounted primary seal and a continuous secondary seal.
- Option 4--Each storage tank must be fitted to a vapor control system. Two vapor control systems which have been analyzed in detail include: a steam-regenerated carbon adsorption system; and a thermal oxidation system.
- Option 5--Prohibit the storage of benzene in tanks.

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Source: EPA, Benzene Emissions from Benzene Storage Tanks--Background Information for Proposed Standards (Research Triangle Park, North Carolina: December 1980 [EPA-450/3-80-034a]), p. 1-3.



Four model plants were developed--a large production facility with seven tanks, a small facility with four tanks, a benzene consumer with two tanks and a bulk storage facility with two tanks. The model plants varied for two different assumptions: 1) that all tanks were new, and 2) that all tanks were existing (new refers to tanks built after May 1978 and existing refers to older tanks). The model plants were developed on the basis of an industry survey which gathered information with respect to the size and number of tanks each firm had. It is unclear how well the model plants represent the true preregulation control conditions in each plant; the absence of negative industry comments on model plant tank sizes and roof types may indicate a relatively close correspondence. Exhibit 4-8 describes the model plants which were used.

In extrapolating from model plants to the industry, EPA categorized each facility as being similar to one of the models. Differences from the model were not taken into account which introduced error into the extrapolation. Exhibits 4-9 and 4-10 summarize the control requirements under each regulatory option and for each pre-regulation tank type. The exhibits describe the specific additions which would have to be made to each tank depending on its pre-regulation characteristics.

Exhibit 4-9 should be interpreted as follows: A new storage tank with an external floating roof and primary and secondary seals (EFRss) would need no modifications to comply with control option one. To meet option 2, however, it would have to be modified to have a contact internal floating roof with liquid mounted primary seal (cIFRps). Generally, the left most column on the table represents the pre-standard tank type and the entries in each column indicate the type of tank to which it would have to be modified, given each control option. Exhibit 4-10 should be interpreted similarly.

In estimating the costs of each of these modifications, EPA defined capital costs as the investment for control equipment and costs of installation. Data were obtained from vendors and EPA reports for five tank sizes. EPA used a series of linear regressions to predict costs for other tank sizes at model facilities.

Capital costs were annualized using a capital recovery rate of 16.27 percent for floating roofs and seals and 13.15 percent for all other hardware. These rates were based on an assumed lifetime of ten years for internal and external floating roofs and seals and a fifteen year life for other hardware. It was also based on the assumption that the real interest rate on capital was ten percent. To account for property taxes, insurance, and administrative expenses, the recovery rates were increased by an additional 4 percent, to 20.27 and 17.15, respectively.

In addition to capital costs, EPA added a five percent maintenance charge per year when a fixed roof tank was converted to an internal floating roof tank. Biannual inspections were assumed in that case at \$200 annually. An additional inspection costing \$1,000 (\$200 annualized) was assumed to occur every five years.



**EXHIBIT 4-8**  
**MODEL BENZENE STORAGE PLANTS**

| Type of Model Plant                                                       | Tank Dimensions<br>(Diameter/Height)<br>(Meters) (Feet) |        | Existing Tank Type a/<br>(CTG as Baseline) | New Tank Type<br>(NSPS as Baseline) | Tank Size<br>3<br>(10 Liters) | Annual<br>Throughput<br>6<br>(10 Liters/Year) | Annual b/<br>Turnovers |
|---------------------------------------------------------------------------|---------------------------------------------------------|--------|--------------------------------------------|-------------------------------------|-------------------------------|-----------------------------------------------|------------------------|
| BENZENE PRODUCER                                                          |                                                         |        |                                            |                                     |                               |                                               |                        |
| Large Facility (throughput of 224.6 × 10 <sup>6</sup> liters/year):       |                                                         |        |                                            |                                     |                               |                                               |                        |
| 12/9                                                                      | (40/30)                                                 | ncIFR  | ncIFR                                      | ncIFR                               | 980                           | 117.1                                         | 119                    |
| 18/12                                                                     | (60/39.8)                                               | EFRRps | EFRRps                                     | EFRRps                              | 2,930                         | 38.3                                          | 13                     |
| 8/5                                                                       | (25/18)                                                 | clFRps | clFRps                                     | ncIFR                               | 240                           | 28.7                                          | 119                    |
| 9/9                                                                       | (30/30)                                                 | clFRps | clFRps                                     | ncIFR                               | 660                           | 78.8                                          | 119                    |
| 13/13                                                                     | (42/41.8)                                               | ncIFR  | ncIFR                                      | ncIFR                               | 1,640                         | 21.4                                          | 13                     |
| 24/9                                                                      | (80/30)                                                 | ncIFR  | ncIFR                                      | ncIFR                               | 3,990                         | 52.1                                          | 13                     |
| 27/15                                                                     | (90/48)                                                 | ncIFR  | ncIFR                                      | ncIFR                               | 8,630                         | 112.8                                         | 13                     |
| Small Facility (throughput of 46.3 × 10 <sup>6</sup> liters/year):        |                                                         |        |                                            |                                     |                               |                                               |                        |
| 3/11                                                                      | (10/36)                                                 | FR     | FR                                         | FR                                  | 80                            | 6.5                                           | 81                     |
| 13/13                                                                     | (42/41.8)                                               | ncIFR  | ncIFR                                      | ncIFR                               | 1,650                         | 11.0                                          | 7                      |
| 8/11                                                                      | (24/35.9)                                               | ncIFR  | ncIFR                                      | ncIFR                               | 490                           | 39.8                                          | 81                     |
| 32/7                                                                      | (104/24)                                                | clFRps | clFRps                                     | ncIFR                               | 5,280                         | 35.3                                          | 7                      |
| BENZENE CONSUMER (throughput of 42.1 × 10 <sup>6</sup> liters/year):      |                                                         |        |                                            |                                     |                               |                                               |                        |
| 12/11                                                                     | (42/35.9)                                               | ncIFR  | ncIFR                                      | ncIFR                               | 1,240                         | 11.2                                          | 9                      |
| 18/15                                                                     | (60/43)                                                 | clFRps | clFRps                                     | ncIFR                               | 3,410                         | 30.9                                          | 9                      |
| BULK STORAGE TERMINAL (throughput of 42.1 × 10 <sup>6</sup> liters/year): |                                                         |        |                                            |                                     |                               |                                               |                        |
| 12/11                                                                     | (40/35.9)                                               | ncIFR  | ncIFR                                      | ncIFR                               | 1,240                         | 11.2                                          | 9                      |
| 18/15                                                                     | (60/43)                                                 | clFRps | clFRps                                     | ncIFR                               | 3,410                         | 30.9                                          | 9                      |

a/ o FR-fixed roof tank;

o EFRps-external floating-roof tank with a primary seal;

o EFRss-external floating-roof tank with primary and secondary seals;

o ncIFR-noncontact internal floating-roof tank;

o clFRps-contact internal floating-roof tank with primary seal.

CTG = Control Techniques Guidelines, 1977.

NSPS = New Source Performance Standards.

b/ Annual Turnovers =  $\frac{\text{Annual Throughput}}{\text{Tank Size}}$

SOURCE: EPA, Benzene Emissions from Benzene Storage Tanks-Background Information for Proposed Standards (RTP, N.C.: December 1980 [EPA 450/3-80-34a]) p. 3-21.

## EXHIBIT 4-9

IMPACTS OF EACH CONTROL OPTION ON  
NEW BENZENE STORAGE TANKS a/

| New<br>Storage<br>Tank | Control Option |          |          |                                                        |
|------------------------|----------------|----------|----------|--------------------------------------------------------|
|                        | <u>1</u>       | <u>2</u> | <u>3</u> | <u>4</u>                                               |
| FR                     | IFRps          | cIFRps   | cIFRss   |                                                        |
| EFRss                  | --             | cIFRps   | cIFRss   | Vapor control<br>system                                |
| ncIFR                  | --             | cIFRps   | ccIFRss  | A. Carbon<br>adsorption<br><br>B. Thermal<br>oxidation |
| cIFRps                 | --             | --       | cIFRss   |                                                        |

- a/ • FR - fixed-roof tank;
- EFRss - external floating-roof tank with primary and secondary seals;
  - ncIFR - noncontact internal floating-roof tank;
  - cIFRps - contact internal floating-roof tank with liquid-mounted primary seal;
  - cIFRss - contact internal floating-roof tank with liquid-mounted primary seal and continuous secondary seal.

Source: EPA, Benzene Emissions from Benzene Storage Tanks--Background Information for Proposed Standards (Research Triangle Park, North Carolina: December 1980 [EPA 450/3-80-034a]).

## EXHIBIT 4-10

IMPACTS OF EACH CONTROL OPTION ON  
EXISTING BENZENE STORAGE TANKS a/

| Existing<br>Storage<br>Tank | Control Option |          |                  |                  |                                   |
|-----------------------------|----------------|----------|------------------|------------------|-----------------------------------|
|                             | <u>1</u>       | <u>2</u> | <u>3</u>         | <u>4</u>         | <u>5</u>                          |
| FR                          | IFRps          | IFRps    | cIFRps           | cIFRps           | Vapor control<br>system           |
| EFRps                       | --             | EFRss    | cIFRps <u>b/</u> | cIFRss <u>b/</u> | A. Carbon<br>adsorption <u>b/</u> |
| ncIFR                       | --             | --       | cIFRps <u>c/</u> | cIFRss           | B. Thermal<br>oxidation <u>b/</u> |
| cIFRps                      | --             | --       | --               | cIFRss           |                                   |

- a/ • FR - fixed-roof tank;
- EFRss - external floating-roof tank with primary and secondary seals;
  - ncIFR - noncontact internal floating-roof tank;
  - cIFRps - contact internal floating-roof tank with liquid-mounted primary seal;
  - cIFRss - contact internal floating-roof tank with liquid-mounted primary seal and continuous secondary seal.

b/ Requires addition of fixed roof to external floating-roof tank.

c/ Requires replacement of or equivalency determination for noncontact internal floating roof.

Source: EPA, Benzene Emissions from Benzene Storage Tanks--Background Information for Proposed Standards (Research Triangle Park, North Carolina: December 1980 [EPA 450/3-80-034a]).

Where a vapor control system was required, EPA added an additional one percent of installed capital cost. Also included were 4¢/kwh for electricity, 7¢/m<sup>3</sup> for gas, and \$7.23/metric ton for steam. One person-year of labor at \$8/hour for 2,000 hours/year was assumed for maintenance. Monitoring costs were estimated in terms of the cost of necessary equipment and parts. These costs were calculated for new and old tanks at the model large and small production, consumption and bulk storage facilities. Exhibits 4-11 and 4-12 summarize these EPA compliance cost estimates.

The cost estimates assume no change in number of tanks or quantity of benzene stored over the time period and in particular, no changes in quantity as a response to the new regulatory environment. Instead, the expected five percent annual increase in total benzene storage capacity is accounted for by postulating an increase in the number of facilities, not an increase in the capacity per facility. Thus, the individual plant control costs will be understated if existing facilities respond to the increased demand for benzene storage by expanding the size of their existing storage facilities.

Very importantly, emissions of other toxic substances to air, water, and solid waste as a result of these standards were not incorporated among costs. For example, a thermal oxidation unit could emit 15,000 kg/year of SO<sub>x</sub> and 5,000 kg/year of NO<sub>x</sub> to air. Under a steam-regenerated carbon adsorption system, a maximum of 9,100 liters of benzene-contaminated water could be released and 5,700 liters under thermal oxidation.

EPA estimated industry wide costs by multiplying large model plant costs by the number of large plants in the industry, the bulk storage plant model by the number of bulk storage plants, and so forth. Total benzene storage capacity was assumed to increase at the same rate as benzene usage--five percent annually from 1979 to 1990. The number of storage facilities in each model plant category was extrapolated to 1990 by multiplying by five percent per year (Exhibit 4-13), and the estimates of compliance costs are displayed in Exhibit 4-14.

There are several sources of uncertainty in the EPA cost analysis. The range of uncertainty which may be involved is difficult to estimate on the basis of available data.

- The baseline for the analysis uses a combination of current standards and current practices. If benzene tank owners are in violation of previous standards, compliance with the new standard would actually cost more than the analysis indicates.
- At best, the plant costs described are short-run compliance costs shared by tank owners and their customers. Effects on related industries are not included in these cost estimates.

EXHIBIT 4-11  
EPA ESTIMATES OF ANNUALIZED COSTS FOR EXISTING MODEL PLANTS  
(1979 dollars)

| Parameter                     | a/          |             |             |          |           |
|-------------------------------|-------------|-------------|-------------|----------|-----------|
|                               | 1           | 2           | Option<br>3 | 4        | 5(A) 5(B) |
| <b>Large benzene producer</b> |             |             |             |          |           |
| Capital recovery charge b/    | NA          | \$2,100     | \$33,100    | \$43,200 | \$41,500  |
| Maintenance cost c/           | NA          | NA          | NA          | NA       | 2,400     |
| Inspection fee d/             | NA          | NA          | NA          | NA       | NA        |
| Utilities cost e/             | NA          | NA          | NA          | NA       | 9,400     |
| Operating labor cost          | NA          | NA          | NA          | NA       | 16,000    |
| Emission monitoring cost      | NA          | NA          | NA          | NA       | 2,500     |
| Total Annualized Cost         | NA          | 2,100       | 33,100      | 43,200   | 71,800    |
| <b>Small benzene producer</b> |             |             |             |          |           |
| Capital recovery charge b/    | 1,400-1,500 | 1,400-1,500 | 7,500       | 13,300   | 35,700    |
| Maintenance cost c/           | 400-400     | 400-400     | 400         | 500      | 2,100     |
| Inspection fee d/             | 400-400     | 400-400     | 400         | 400      | NA        |
| Utilities cost e/             | NA          | NA          | NA          | NA       | 9,400     |
| Operating labor cost          | NA          | NA          | NA          | NA       | 16,000    |
| Emission monitoring cost      | NA          | NA          | NA          | NA       | 2,500     |
| Total Annualized Cost         | 2,200-2,300 | 2,200-2,300 | 8,300       | 14,200   | 65,700    |
| <b>Benzene consumer</b>       |             |             |             |          |           |
| Capital recovery charge b/    | NA          | NA          | 3,500       | 6,800    | 32,300    |
| Maintenance cost c/           | NA          | NA          | NA          | NA       | 1,900     |
| Inspection fee d/             | NA          | NA          | NA          | NA       | NA        |
| Utilities cost e/             | NA          | NA          | NA          | NA       | 9,400     |
| Operating labor cost          | NA          | NA          | NA          | NA       | 16,000    |
| Emission monitoring cost      | NA          | NA          | NA          | NA       | 2,500     |
| Total Annualized Cost         | NA          | NA          | 3,500       | 6,800    | 62,100    |

(continued on next page)



EXHIBIT 4-11 (continued)  
EPA ESTIMATES OF ANNUALIZED COSTS FOR EXISTING MODEL PLANTS  
(1979 dollars)

| Parameter                  | a/<br>Option |    |       |        |           |
|----------------------------|--------------|----|-------|--------|-----------|
|                            | 1            | 2  | 3     | 4      | 5(A) 5(B) |
| Bulk storage terminal      | NA           | NA | 3,500 | 6,800  | 32,300    |
| Capital recovery charge b/ | NA           | NA | NA    | NA     | 1,900     |
| Maintenance cost c/        | NA           | NA | NA    | NA     | NA        |
| Inspection fee d/          | NA           | NA | NA    | 11,600 | 9,400     |
| Utilities cost e/          | NA           | NA | NA    | 16,000 | 16,000    |
| Operating labor cost       | NA           | NA | NA    | 2,500  | 2,500     |
| Emission monitoring cost   | NA           | NA | 3,500 | 6,800  | 62,100    |
| Total Annualized Cost      | NA           | NA |       |        |           |

a/ NA = Not applicable.

b/ The capital recovery factor is 20.27 percent for internal and external floating roofs and seals, and 17.15 percent for all other hardware.

c/ Determined as 5 percent of total capital costs for Options 1, 2, 3, 4, and as 1 percent of total capital costs for Options 5(A) and 5(B).

d/ Inspection fee includes charges of \$200 for visual inspections twice per year and \$200 a year for a 5-year thorough inspection of seals (including cleaning and degassing costs) for both noncontact and contact internal floating roofs.

e/ Utilities cost consists of steam and electrical requirements for Option 5(A) and natural gas and electrical requirements for Option 5(B).

Source: EPA, Benzene Emissions from Benzene Storage Tanks-Background Information for Proposed Standards (RTP, N.C.: December, 1980 [EPA-450/3-80-034a]), pp. 7-46, 7-47.

EXHIBIT 4-12  
EPA ESTIMATES OF ANNUALIZED COSTS FOR NEW MODEL PLANTS  
(1979 dollars)

| Parameter                     | Option      |          |          |           |
|-------------------------------|-------------|----------|----------|-----------|
|                               | 1           | 2        | 3        | 4(A) 4(B) |
| <u>Large benzene producer</u> |             |          |          |           |
| Capital recovery charge b/    | NA          | \$15,700 | \$23,800 | \$45,600  |
| Maintenance cost c/           | NA          | NA       | NA       | 2,700     |
| Inspection fee d/             | NA          | NA       | NA       | NA        |
| Utilities cost e/             | NA          | NA       | NA       | 11,600    |
| Operating labor cost          | NA          | NA       | NA       | 16,000    |
| Emission monitoring cost      | NA          | NA       | NA       | 2,500     |
| Total Annualized Cost         | NA          | 15,700   | 23,800   | 78,400    |
| <u>Small benzene producer</u> |             |          |          |           |
| Capital recovery charge b/    | 1,200-1,300 | 9,500    | 14,000   | 41,500    |
| Maintenance cost c/           | 300-300     | 300      | 400      | 2,400     |
| Inspection fee d/             | 400-400     | 400      | 400      | NA        |
| Utilities cost e/             | NA          | NA       | NA       | 11,600    |
| Operating labor cost          | NA          | NA       | NA       | 16,000    |
| Emission monitoring cost      | NA          | NA       | NA       | 2,500     |
| Total Annualized Cost         | 1,900-2,000 | 9,700    | 14,800   | 74,000    |
| <u>Benzene consumer</u>       |             |          |          |           |
| Capital recovery charge b/    | NA          | 3,100    | 5,700    | 38,700    |
| Maintenance cost c/           | NA          | NA       | NA       | 2,300     |
| Inspection fee d/             | NA          | NA       | NA       | NA        |
| Utilities cost e/             | NA          | NA       | NA       | 11,600    |
| Operating labor cost          | NA          | NA       | NA       | 16,000    |
| Emission monitoring cost      | NA          | NA       | NA       | 2,500     |
| Total Annualized Cost         | NA          | 3,100    | 5,700    | 71,100    |

(continued on next page).

EXHIBIT 4-12 (continued)  
EPA ESTIMATES OF ANNUALIZED COSTS FOR NEW MODEL PLANTS  
(1979 dollars)

| Parameter                  | a/<br>Option |       |       |               |
|----------------------------|--------------|-------|-------|---------------|
|                            | 1            | 2     | 3     | 4(A) 4(B)     |
| Bulk storage terminal      |              |       |       |               |
| Capital recovery charge b/ | NA           | 3,100 | 5,700 | 38,700 31,500 |
| Maintenance cost c/        | NA           | NA    | NA    | 2,300 1,800   |
| Inspection fee d/          | NA           | NA    | NA    | NA NA         |
| Utilities cost e/          | NA           | NA    | NA    | 11,600 9,400  |
| Operating labor cost       | NA           | NA    | NA    | 16,000 16,000 |
| Emission monitoring cost   | NA           | NA    | NA    | 2,500 2,500   |
| Total Annualized Cost      | NA           | 3,100 | 5,700 | 71,100 61,200 |

a/ NA = Not applicable.

b/ The capital recovery factor is 20.27 percent for an internal floating roof and 17.15 percent for all other hardware.

c/ Determined as 5 percent of total capital cost for Options 1, 2, and 3, and as 1 percent of total capital costs for Options 4(A) and 4(B).

d/ Inspection fee includes charges of \$200 for visual inspection twice per year and \$200 per year for a 5-year thorough inspection of seals (including cleaning and degassing costs) for both noncontact and contact internal floating roofs.

e/ Utilities costs consists of steam and electrical requirements for Option 4(A) and natural gas and electrical requirements for Option 4(B).

Source: EPA, Benzene Emissions from Benzene Storage Tanks-Background Information for Proposed Standards (RTP, N.C.: December, 1980 [EPA-450/3-80-034a]), pp. 7-54, 7-55.

## EXHIBIT 4-13

TOTAL PROJECTED NUMBER OF PLANTS WITH BENZENE STORAGE TANKS  
(1979-1990)

| <u>Year</u>        | <u>Large<br/>Benzene<br/>Producer</u> | <u>Small<br/>Benzene<br/>Producer</u> | <u>Benzene<br/>Consumer</u> | <u>Bulk<br/>Storage<br/>Terminal</u> |
|--------------------|---------------------------------------|---------------------------------------|-----------------------------|--------------------------------------|
| 1979 <sup>a/</sup> | 28                                    | 34                                    | 77                          | 4                                    |
| 1980               | 29.4                                  | 35.7                                  | 80.8                        | 4.2                                  |
| 1985               | 37.5                                  | 45.6                                  | 103.2                       | 5.4                                  |
| 1990               | 47.9                                  | 58.2                                  | 131.7                       | 6.8                                  |

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a/ Baseline year.

Source: EPA, Benzene Emissions from Benzene Storage Tanks-  
Background Information for Proposed Standards, (RTP,  
N.C.: December 1980 [EPA-450/3-80-034a]), pp. 6-5.

## EXHIBIT 4-14

TOTAL EPA ESTIMATES OF CAPITAL COSTS AND ANNUALIZED  
COSTS OF CONTROL OPTIONS

| <u>Emissions Source and<br/>Control Option</u> | <u>Total Capital Cost<br/>(thousands of<br/>1980 dollars)</u> | <u>Total Annualized Cost<br/>(thousands of<br/>1980 dollars)</u> |
|------------------------------------------------|---------------------------------------------------------------|------------------------------------------------------------------|
| Existing Benzene<br>Storage Tanks              |                                                               |                                                                  |
| Baseline <u>a/</u> (1979)                      | 0                                                             | 0                                                                |
| 1                                              | 260                                                           | 75                                                               |
| 2                                              | 585                                                           | 45                                                               |
| 3                                              | 7,900                                                         | 1,050                                                            |
| 4                                              | 11,900                                                        | 1,730                                                            |
| 5(A)                                           | 37,800                                                        | 10,800                                                           |
| 5(B)                                           | 31,350                                                        | 10,050                                                           |
| New Benzene<br>Storage Tanks                   |                                                               |                                                                  |
| Baseline <u>a/</u> (1985)                      | 0                                                             | 0                                                                |
| 1                                              | 80                                                            | 22                                                               |
| 2                                              | 1,840                                                         | 110                                                              |
| 3                                              | 2,900                                                         | 280                                                              |
| 4(A)                                           | 12,970                                                        | 3,570                                                            |
| 4(B)                                           | 10,270                                                        | 3,350                                                            |

a/ No additional standard.

Source: EPA, Benzene Emissions from Benzene Storage Tanks-  
Background Information for Proposed Standards, (RTP,  
N.C.: December 1980 [EPA-450/3-80-034a]), pp. 7-61.



- If there is any change in the capacity of existing storage tank facilities, future industry-wide cost estimates may be overstated. Plant owners may be able to add a portion of the expected increase in existing facilities. Because some control technologies are facility specific (as opposed to tank specific), total industry costs could rise more slowly than estimated.

#### 4.3 BENZENE NESHAP EFFECTIVENESS ANALYSIS

Difficulties encountered in the estimation of emission reductions are similar to those associated with compliance cost estimation. For each of the proposed regulations, EPA estimated emission rates for model plants using data assumed to be characteristic of typical facilities in the industry under study. As described above in regard to cost estimates, the model plant data were extrapolated to the entire industries. Estimates of expected emission reductions were adjusted as required to reflect the current status of emission controls used in the various industries. The following section summarizes the results of the EPA analysis in terms of the number of metric tons of emissions expected to be prevented by the various proposed regulatory alternatives.

Unlike the situation that exists for the various regulations limiting the emission of lead and asbestos into the environment, it is possible to make quantitative estimates of the health consequences of the proposed benzene regulations. These estimates are also summarized below. The following section of this chapter will examine the relationship between the two measures of effectiveness: metric tons of emissions prevented, and health benefits.

##### 4.3.1 Estimates of Emissions Prevented by the Proposed Benzene Emission Standards

###### Maleic Anhydride Industry

EPA examined all eight plants producing maleic anhydride from benzene in the estimation of emission reductions.<sup>22</sup> (New facilities and butane based facilities were not discussed.) A model plant was developed for purposes of estimating emissions and was assumed to have a capacity of 22,700 metric tons/year and two storage tanks. Emissions from the storage tanks were not considered in estimating the effectiveness of the various control options.

The model plant emission reduction data were used to estimate total emission reduction for the industry. The eight operating plants were treated as though they were identical to the model plants except for differences in

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<sup>22</sup>As mentioned above, the structure of the Maleic anhydride industry has changed substantially since this analysis was performed. See Footnote 15.

size and control device efficiency. A linear adjustment was made in model plant emissions to take into account size and control differences. Exhibit 4-15 presents EPA's emission reduction estimates derived by these methods.

As in the case of cost estimates, EPA's benzene emission reduction estimates for maleic anhydride production assume two cases of capacity utilization: 56 percent and 100 percent. Thus, emissions estimates are bounds for the production patterns expected over time. Exhibit 4-15 displays estimates only for 100 percent capacity utilization which is expected by 1983. Until that time, these estimates may overstate actual emission reductions achievable through the application of the technologies considered.

As mentioned above in the discussion of costs, the EPA analysis did not incorporate the intermedia effects of the proposed controls on benzene emissions. For example, 44 additional tons per year of benzene and 467 tons of other VOCs would be diverted from air emissions to water. These emissions should in some sense be subtracted from expected air emission reductions to obtain the net emission reductions which would result from controls. Subtracting emissions in water from emissions in air, however, obscures the fact that the emissions present different health hazards. Thus, the net emissions number should be translated into a net health benefits number that takes into account differences in health effects by media.

Exhibit 4-16 presents a more complete picture of emissions effects, presenting expected emissions of benzene and other VOCs by control option, medium, and chemical for the model plant. Where quantities are uncertain, question marks are recorded.

#### Ethylbenzene/Styrene Industry

Emissions estimates were based on sampling tests at three facilities during which the effluent concentrations of benzene were determined. Emission reductions for individual plants were calculated by factoring in actual levels of control in those plants and their actual capacities. The estimates assume 100 percent capacity utilization and because the plants are currently operating at less than full capacity, the total amount of benzene removed is overstated. We revised the estimates of emissions reductions to account for the reduced level of production currently taking place. EPA's estimates and our revised estimates, displayed in Exhibit 4-17, only differ by five to ten percent.

The benefits of other emissions which are controlled simultaneously are not incorporated in EPA's cost/effectiveness analysis. This is partly because their magnitude is unknown. Benefits may therefore be understated. Information with respect to the control of other aromatics is required to fully examine the benefits of the control options.

#### Benzene Storage Tanks

EPA estimated benzene emissions reductions from storage tanks by applying engineering estimates to model tanks. The engineering studies examined emissions under test conditions in which they varied seal condition,

EXHIBIT 4-15  
REDUCTION IN BENZENE EMISSIONS FOR SELECTED CONTROL LEVELS  
MALEIC ANHYDRIDE INDUSTRY a/

|                                    | Capa-<br>city<br>(Metric<br>Tons/Yr) | Total<br>uncon-<br>trolled<br>emis-<br>sions b/<br>(Metric<br>Tons/Yr) | Existing<br>control<br>device<br>efficien-<br>cy (%) | Emissions<br>with<br>existing<br>control c/<br>(Metric<br>Tons/Yr) | 97% Control<br>Allow-<br>able<br>benzene<br>emissions d/<br>(Metric<br>Tons/Yr) | 99% Control<br>Allow-<br>able<br>benzene<br>emissions f/<br>(Metric<br>Tons/Yr) | Incre-<br>mental<br>benzene<br>removed g/<br>(Metric<br>Tons/Yr) |
|------------------------------------|--------------------------------------|------------------------------------------------------------------------|------------------------------------------------------|--------------------------------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------|------------------------------------------------------------------|
| Ashland, Neal W. Va.               | 27,200                               | 1,849                                                                  | 0                                                    | 1,849                                                              | 126                                                                             | 61                                                                              | 65                                                               |
| Koppers, Bridgeville, Pa.          | 15,400                               | 1,047                                                                  | 99                                                   | 26                                                                 | 72                                                                              | 35                                                                              | 0                                                                |
| Monsanto, St. Louis, Mo.           | 38,100                               | 2,589                                                                  | 0                                                    | 2,589                                                              | 177                                                                             | 85                                                                              | 92                                                               |
| DENKA, Houston, Tex.               | 22,700                               | 1,543                                                                  | 97                                                   | 68                                                                 | 105                                                                             | 50                                                                              | 18                                                               |
| Riechhold, Elizabeth, N.J.         | 13,600                               | 924                                                                    | 97                                                   | 41                                                                 | 63                                                                              | 30                                                                              | 11                                                               |
| Reichhold, Morris, Ill.            | 20,000                               | 1,359                                                                  | 90                                                   | 154                                                                | 93                                                                              | 45                                                                              | 48                                                               |
| Tenneco, Fords, N.J.               | 11,800                               | 802                                                                    | 0                                                    | 802                                                                | 55                                                                              | 26                                                                              | 29                                                               |
| U.S. Steel, Neville<br>Island, Pa. | 38,500                               | 2,616                                                                  | 90                                                   | 295                                                                | 179                                                                             | 86                                                                              | 93                                                               |
| Totals                             |                                      | 12,729                                                                 |                                                      | 5,824                                                              | 870                                                                             | 420                                                                             | 356                                                              |

a/ Emission rates are based on: Lawson, J.F., Emission Control Options for the Synthetic Organic Chemicals Manufacturing Industry Maleic Anhydride--Product Report, Hydrosience, Inc. (Prepared for Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina). EPA Contract Number 68-02-2577, March 1978.

b/ Total uncontrolled emissions =  $[(2.6 \text{ kg/hr} \times 8,760 \text{ hr}) + (190 \text{ kg/hr} \times 8,000 \text{ hr})]$   
 $\times \frac{\text{production capacity metric tons/yr}}{\text{model plant capacity 22,700 Metric tons/yr}}$

Based on a benzene conversion rate of 94.5 percent.

c/ Emissions with existing control =  $[(2.6 \text{ kg/hr} \times 8,760 \text{ hr}) + (190 \text{ kg/hr} \times (1\text{-control device efficiency})$   
 $\times 8,000 \text{ hr})] \times \frac{\text{model plant capacity 22,700 Metric tons/yr}}{\text{production capacity metric tons/year}}$

d/Allowable benzene emissions with 97 percent control =  $[(2.6 \text{ kg/hr} \times 8,760 \text{ hr}) + (345.4 \text{ kg/hr} \times 0.03 \times 8,000 \text{ hr})] \times$   
 $(\frac{\text{production capacity/22,700 metric tons/yr}}{\text{conversion rate of 90 percent}})$ . Based on a benzene

e/Incremental benzene removed with 97 percent control = (emissions with existing controls) - (allowable benzene emissions at 97% control).

f/Allowable benzene emissions with 99 percent control =  $[(2.6 \text{ kg/hr} \times 8,760 \text{ hr}) + (345.4 \text{ kg/hr} \times 0.01 \times 8,000 \text{ hr})] \times$   
 $(\frac{\text{production capacity/22,700 metric tons/yr}}{\text{conversion rate of 90 percent}})$ . Based on a benzene

g/Incremental benzene removed with 99 percent control = (emissions with 97 percent controls) - (allowable benzene emissions at 99% control).

Source: EPA, Benzene Emissions from Maleic Anhydride Industry--Background Information for Proposed Standards, (Research Triangle Park, North Carolina: February 1980 [EPA-450/3-80-001a]), p. 4-18.

## EXHIBIT 4-16

CHANGES IN MODEL MALEIC ANHYDRIDE PLANT EMISSIONS DUE TO CONTROL OPTIONS

| <u>Media and Chemical</u>                            | <u>Carbon Adsorption</u> |                                      | <u>Thermal Incineration</u> |                    |
|------------------------------------------------------|--------------------------|--------------------------------------|-----------------------------|--------------------|
|                                                      | <u>97% Control</u>       | <u>99% Control</u>                   | <u>97% Control</u>          | <u>99% Control</u> |
| <u>Air</u>                                           |                          |                                      |                             |                    |
| Benzene (metric tons /year)                          | -1440                    | -1490                                | -1440                       | -1490              |
| Other VOCs                                           | ?                        | ?                                    | ?                           | ?                  |
| SO <sub>2</sub> (maximum emission, metric tons/year) | 0                        | 0                                    | + 26                        | + 64               |
| NOx (maximum emission)                               | 0                        | 0                                    | 0.27 g/sec                  | 50-200 ppmv        |
| Particulates                                         | 0                        | 0                                    | ?                           | ?                  |
| <u>Water</u>                                         |                          |                                      |                             |                    |
| Benzene (metric tons/year)                           | + 40                     | + 40                                 | 0                           | 0                  |
| <u>Solid Waste</u>                                   |                          |                                      |                             |                    |
| Total Solid Waste (Mg/year)                          | 7.4                      | 7.6 (or zero, if waste is reclaimed) |                             |                    |

Source: EPA, Benzene Emissions from Ethylbenzene/Styrene Industry- Background Information for Proposed Standards (Research Triangle Park, North Carolina: August 1980 [EPA-450/3-29-035a]).

## EXHIBIT 4-17

ESTIMATED INDUSTRY-WIDE EMISSION REDUCTIONS  
FOR EACH REGULATORY OPTION FOR  
ETHYLBENZENE/STYRENE INDUSTRY

| Control Option | Revised Estimate<br>Benzene Removed<br>(metric tons/year) | EPA Estimate<br>Benzene Removed<br>(metric tons/year) <u>a/</u> |
|----------------|-----------------------------------------------------------|-----------------------------------------------------------------|
| 85 percent     | 1,225                                                     | 1,365                                                           |
| 94 percent     | 1,588                                                     | 1,790                                                           |
| 99 percent     | 1,810                                                     | 1,920                                                           |

a/Source: EPA, Benzene Emissions from Ethylbenzene/Styrene Industry--Background Information for Proposed Standards (Research Triangle Park, North Carolina: August 1980 [EPA-450/3-29-035a]), pp. 6-6 through 6-10.



temperature, wind speed, tank size, and tank type. EPA's analysis revealed that a 50 percent error in measuring wind speed can cause an error of 25-50 percent in estimating the seal loss (emission) from internal floating roof tanks and that a 50 percent error in measuring vapor pressure can lead to equivalent errors in seal loss and fitting loss estimated for both internal and external floating roof tanks. Therefore, extrapolation to the entire industry from model tank data will likely result in estimates of emission reductions with a high degree of uncertainty.

EPA did not examine existing seal conditions to develop an estimate of baseline emissions, but rather relied on a study by the California Air Resources Board (CARB) which surveyed the condition of seal gaps in external floating roof tanks. From the CARB study, the conclusion was drawn that 65 percent of all tanks have no seal gaps. It was also assumed that the other 35 percent had seal gaps of 1.3 inches<sup>2</sup>/ft. of tank diameter. The CARB external floating roof survey may not be representative of the current condition of all tanks nationwide, but is apparently the best indicator available. Baseline emissions are summarized in Exhibit 4-18 for model tanks.

Exhibits 4-19 and 4-20 represent post regulation estimated emissions for each control option. Exhibit 4-21 presents estimates of national emissions extrapolated from model plants to actual plants and plants expected to exist in 1985. The estimate of capacities in 1985 was derived from industry publications. The extrapolation from model plants to actual plants raises the same uncertainties as were raised in the estimation of costs. That is, the estimates are good to the extent that actual plants are like the model plants.

#### 4.3.2 Estimates of Health Benefits of the Proposed Benzene Emission Standards

Unlike the situation that exists for the various regulations which limit the use and emission of lead or asbestos into the environment, it is possible to make quantitative estimates of the health consequences of the proposed regulations which would limit benzene air pollution from maleic anhydride plants, ethylbenzene-styrene manufacturing, and benzene storage facilities. This is possible because numerous epidemiologic studies have been performed concerning the relationship between human exposure to benzene and the development of disease. From several of these studies it has been possible to estimate directly the relationship between the amount of exposure to benzene and the development of certain types of leukemia. Given the human relationship between benzene exposure and the risk of leukemia, it is possible to estimate the health risk, in terms of leukemia incidence, produced by present emission levels and future emission levels under various regulatory scenarios. The following discussion will review the attempts that have been made to estimate the impact of these regulations, and how these results might be used to compare regulatory alternatives.

It should be noted that although it is possible to estimate the impact of benzene emission regulations on the future incidence of leukemia in the United States, it does not imply that the full scope of the effects of these regulations on the public health can yet be measured. As will be discussed

## EXHIBIT 4-18

EPA ESTIMATES OF BASELINE EMISSIONS  
FROM MODEL BENZENE STORAGE TANK FACILITIES

| <u>Type of Plant</u>   | <u>Existing Model Plant<br/>(Metric tons per Year)</u> | <u>New Model Plant <u>a/</u><br/>(Metric tons per year)</u> |
|------------------------|--------------------------------------------------------|-------------------------------------------------------------|
| Large benzene producer | 44                                                     | 40                                                          |
| Small benzene producer | 13                                                     | 21 <u>b/</u>                                                |
| Benzene consumer       | 6.5                                                    | 11 <u>b/</u>                                                |
| Bulk storage terminal  | 6.5                                                    | 11 <u>b/</u>                                                |

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a/ New plants are those built after May 18, 1978 which must comply with the Petroleum Liquid Storage Tank, New Source Performance Standards.

b/ Baseline emissions from new model plants are in most cases higher than those from existing plants because new plants are assumed to comply only with the minimum requirements of the Petroleum Liquid Storage Tank New Source Performance Standards.

Source: EPA, Benzene Emissions from Storage Tanks-Background Information for Proposed Standards (RTP, NC: December 1980 [EPA-450/3-80-034a]), p. 3-23.

## EXHIBIT 4-19

EMISSIONS FOR CONTROL OPTIONS -- EXISTING MODEL PLANTS  
(Fixed-Roof Tank Control Techniques Guidelines as Baseline)

| Control<br>Option      | Large<br>Producer<br>(Metric tons<br>per year) | Small<br>Producer<br>(Metric tons<br>per year) | Consumer<br>(Metric tons<br>per year) | Storage<br>Bulk<br>Terminal<br>(Metric tons<br>per year) |
|------------------------|------------------------------------------------|------------------------------------------------|---------------------------------------|----------------------------------------------------------|
| 0 (Baseline) <u>a/</u> | 44                                             | 13                                             | 6.5                                   | 6.5                                                      |
| 1                      | 44                                             | 12 - 13 <u>b/</u>                              | 6.5                                   | 6.5                                                      |
| 2                      | 36                                             | 12 - 13 <u>b/</u>                              | 6.5                                   | 6.5                                                      |
| 3                      | 13                                             | 6.3                                            | 3.3                                   | 3.3                                                      |
| 4                      | 7.7                                            | 3.9                                            | 2.0                                   | 2.0                                                      |
| 5(A) <u>c/</u>         | 9.1                                            | 2.2                                            | 1.1                                   | 1.1                                                      |
| 5(B) <u>d/</u>         | 6.8                                            | 1.7                                            | 0.83                                  | 0.83                                                     |
| 6                      | 0                                              | 0                                              | 0                                     | 0                                                        |

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a/ No additional standard.

b/ Range of emissions for control option which allows the use of contact and noncontact internal floating roofs, respectively, in affected tanks.

c/ Steam-regenerated carbon adsorption system.

d/ Thermal oxidation system.

Source: EPA, Benzene Emissions from Storage Tanks-Background Information for Proposed Standards (RTP, NC: December 1980 [EPA-450/3-80-034a]), p. 6-2.

## EXHIBIT 4-20

EMISSIONS FOR CONTROL OPTIONS -- NEW MODEL PLANTS  
(Petroleum Liquid Storage Tank NSPS as Baseline)

| <u>Control<br/>Option</u>        | <u>Large<br/>Producer<br/>(Metric tons<br/>per year)</u> | <u>Small<br/>Producer<br/>(Metric tons<br/>per year)</u> | <u>Consumer<br/>(Metric tons<br/>per year)</u> | <u>Storage<br/>Bulk<br/>Terminal<br/>(Metric tons<br/>per year)</u> |
|----------------------------------|----------------------------------------------------------|----------------------------------------------------------|------------------------------------------------|---------------------------------------------------------------------|
| 0 (Baseline) <u>a/</u> <u>b/</u> | 40                                                       | 21                                                       | 11                                             | 11                                                                  |
| 1                                | 40                                                       | 20 - 21 <u>c/</u>                                        | 11                                             | 11                                                                  |
| 2                                | 13                                                       | 6.3                                                      | 3.3                                            | 3.3                                                                 |
| 3                                | 7.7                                                      | 3.9                                                      | 2.0                                            | 2.0                                                                 |
| 4(A) <u>d/</u>                   | 9.1                                                      | 2.2                                                      | 1.1                                            | 1.1                                                                 |
| 4(B) <u>e/</u>                   | 6.8                                                      | 1.7                                                      | 0.83                                           | 0.83                                                                |
| 5                                | 0                                                        | 0                                                        | 0                                              | 0                                                                   |

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a/ No additional standard.

b/ Baseline emissions from new model facilities are higher than those from existing facilities because new facilities are assumed to comply with the minimum requirements of the Petroleum Liquid Storage Tank NSPS.

c/ Baseline emissions for control option which allows the use of contact and noncontact internal floating roofs, respectively, in affected tanks.

d/ Steam-regenerated carbon adsorption system.

e/ Thermal oxidation system.

Source: EPA, Benzene Emissions from Storage Tanks-Background Information for Proposed Standards (RTP, NC: December 1980 [EPA-450/3-80-034a]), p. 6-3.

## EXHIBIT 4-21

## TOTAL ESTIMATED NATIONAL EMISSIONS

| Emissions<br>Source and<br>Control Option | National<br>Emissions<br>(Metric Tons/Year) | Emissions<br>Prevented<br>(Metric Tons/Year) |
|-------------------------------------------|---------------------------------------------|----------------------------------------------|
| <u>Existing Benzene Storage Tanks</u>     |                                             |                                              |
| 0-Baseline <u>a/</u> (1979)               | 2,200                                       | 0                                            |
| 1                                         | 2,200                                       | 0                                            |
| 2                                         | 2,000                                       | 200                                          |
| 3                                         | 850                                         | 1,350                                        |
| 4                                         | 510                                         | 1,690                                        |
| 5(A)                                      | 420                                         | 1,780                                        |
| 5(B)                                      | 320                                         | 1,880                                        |
| <u>New Benzene Storage Tanks</u>          |                                             |                                              |
| 0-Baseline <u>a/</u> (1985)               | 930                                         | 0                                            |
| 1                                         | 920                                         | 10                                           |
| 2                                         | 290                                         | 640                                          |
| 3                                         | 170                                         | 760                                          |
| 4(A)                                      | 140                                         | 790                                          |
| 4(B)                                      | 110                                         | 820                                          |

a/ No additional standard.

Source: EPA, Benzene Emissions for Benzene Storage Tanks--Background Information for Proposed Standards (Research Triangle Park, North Carolina: December 1980 [EPA-450-/3-80-034a]), p. 7-61.



below, exposure to benzene is known or suspected to produce many other health effects, including increased incidence of certain other types of cancer, chromosome abnormalities (whose significance for public health is not yet known), and depressions in bone marrow function. Also, uncertainties surrounding the exact magnitude of the health risk posed by benzene exposure (arising from several sources in the estimation procedure) may make the use of the risk assessment results unsuitable for making fine distinctions between regulatory alternatives.

#### Methodology Used to Estimate the Health Risks Produced by Benzene Exposure

To our knowledge, the only studies which specifically estimate the reduction in health risk brought about by the proposed regulations are contained in the appendices to EPA's Background Documents for the proposed standards.<sup>23</sup> These studies use basically the same methods to estimate the emissions from facilities, the number of people exposed to benzene, the level to which they are exposed, and the increases in the rate of leukemia incidence that could be expected to occur as a result of the exposure. As described above, emission estimates from a model plant or set of model plants, are used to estimate emission levels for each individual facility. These emission levels are then used as inputs to standard air pollution diffusion models, which generate the average and maximum exposure levels that would be expected to occur at various distances from each facility. Detailed census data are then used to estimate the number of people exposed to the various levels of benzene around the facilities. The total population exposure is used to estimate changes in leukemia incidence, assuming a linear relationship exists between total cumulative lifetime exposure and increased cancer incidence. The dose-response relationship is taken from a previous risk assessment for benzene exposure prepared by the EPA Carcinogen Assessment Group.<sup>24</sup>

For each regulation, emission rates were estimated using data from model plants assumed to have characteristics typical of facilities in the industry under study or in various segments thereof. As described above, the reductions in emissions that would be brought about by each regulatory alternative under study were estimated by making predictions about the kind of technology that would be employed to comply with each standard, and the effectiveness of these technologies at reducing emissions. In most cases the regulatory alternatives were technology-based, so that the reduction in emissions simply corresponded to the application of a particular technology to all appropriate sources. These emission reduction estimates are summarized in Exhibit 4-22.

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<sup>23</sup> Benzene Emissions from Maleic Anhydride Industry..., op. cit., Benzene Emission from Ethylbenzene/ Styrene Industry..., op. cit., Benzene Emission from Benzene Storage Tanks..., op. cit.

<sup>24</sup> U.S. Environmental Protection Agency, "Carcinogen Assessment Group's Final Report on Population Risk to Ambient Benzene Exposure," January 10, 1979, EPA-450/5-80-004.

## EXHIBIT 4-22

## REDUCTIONS IN EMISSIONS BROUGHT ABOUT BY BENZENE REGULATIONS

|                                           | <u>Emissions<br/>(Metric Tons/Year)</u> | <u>Percent<br/>Reduction</u> |
|-------------------------------------------|-----------------------------------------|------------------------------|
| <b>Maleic Anhydride Manufacturing</b>     |                                         |                              |
| Uncontrolled                              | 12,700                                  |                              |
| Present Controls                          | 5,800                                   |                              |
| "97%" Option                              | 870 <u>a/</u><br>[900-940]              | 85 <u>b/</u>                 |
| "99%" Option                              | 420                                     | 92 <u>b/</u>                 |
| Butane-for-Benzene Substitution           | 0                                       | 100                          |
| <hr/>                                     |                                         |                              |
| <b>Ethylbenzene/Styrene Manufacturing</b> |                                         |                              |
| Uncontrolled                              | 6,700                                   |                              |
| Present Controls                          | 2,000                                   |                              |
| Option A ("85%")                          | 635                                     | 68 <u>b/</u>                 |
| Option B ("94%")                          | 210                                     | 89 <u>b/</u>                 |
| Option C ("99%")                          | 80                                      | 96 <u>b/</u>                 |
| Option D ("100%")                         | 0                                       | 100                          |
| <hr/>                                     |                                         |                              |
| <b>Benzene Storage Facilities</b>         |                                         |                              |
| 1980: Present Controls                    | 2,300                                   |                              |
| Various Control Options <u>c/</u>         | 2,300-330                               | 0-86 <u>b/</u>               |
| 1985: Present Controls                    | 3,100                                   |                              |
| Various Control Options <u>c/</u>         | 3,100-420                               | 0-86 <u>d/</u>               |
| 1990: Present Controls                    | 4,100                                   |                              |
| Various Control Options <u>c/</u>         | 4,100-540                               | 0-87 <u>e/</u>               |

a/ The 870 figure assumes no control system failures. The range [900-940] assumes various numbers of control system failures.

b/ Compared to 1980 levels.

c/ The reductions produced by each control option are described in the previous section.

d/ Compared to predicted 1985 levels.

e/ Compared to predicted 1990 levels.

In the case of maleic anhydride production, approximately 75 percent of the present emissions come from two plants; 1849 metric tons/year from the Ashland plant in Neal, West Virginia and 2589 metric tons/year from the Monsanto plant in St. Louis, Missouri. Under the projected control scenarios, the bulk of the reduction in emissions would occur at these two plants, which currently have no emission control equipment.<sup>25</sup> The implication of this geographical pattern of emission reduction is discussed further below.

Air Dispersion Models for Benzene Pollution. All three studies use basically the same air pollution dispersion model to predict changes in benzene levels in air around the various facilities brought about by the regulation. The model used, the Industrial Source Complex Dispersion (ISCD) model, is a standard computer model which predicts short-term and long-term pollution levels on the basis of hourly emission data and meteorological conditions at the site in question. Because of the expense of obtaining needed input data and running this model, it was necessary to specify input data for only a few sets of localities and meteorological conditions, e.g., it was assumed that all benzene storage facilities were located in rural areas on the Gulf Coast (most of them are) and that maleic anhydride plants all experienced meteorological conditions similar to Pittsburgh, Pa. (two of them are located there). Source characteristics (e.g., stack or emission height, emission volume) were also programmed into the model.

The models were used to generate information concerning the average benzene levels at various distances around specific sources, out to a distance of 20 kilometers (beyond this distance, modeling results are not considered reliable). These average benzene levels were used to calculate leukemia risks faced by populations around particular point sources, as will be described below.

The particular model chosen, and the simplifying assumptions made in the modelling of the dispersion of pollutants are entirely reasonable in light of the cost of using such models and the difficulties in accurately specifying meteorological conditions and source characteristics for a large number of sources. Previous analyses of models used to predict benzene levels around point sources have, however, pointed out the relatively high sensitivity of the modelling results to the exact form of the model chosen, and demonstrated that past modelling efforts have often failed to produce results consistent with monitoring data gathered around such point sources.<sup>26</sup> For these reasons, we believe that the claims made in the Maleic Anhydride background documents<sup>27</sup> that the modeling results were likely to be correct within a factor of 2 are likely to be somewhat optimistic.

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<sup>25</sup>Both plants are currently reducing their emissions. See Footnote 15.

<sup>26</sup>Center for Policy Alternatives, Massachusetts Institute of Technology, Discussion and Critique of the Airways Assessment Group's Report on Population Risk Due to Atmospheric Exposure to Benzene, Prepared for the Office of Air Quality Planning and Standards, U.S. Environmental Protective Agency, May 7, 1980.

<sup>27</sup> Ibid., p. E-23.

Estimates of Populations at Risk, Levels of Exposure and Risk of Leukemia. The method used in the background documents (again the same for all three source classes) to estimate the populations at risk around the various facilities applied highly detailed census data to estimate the numbers of people living within various distances of the emission sources. Population density data for a square-mile region around each source were used to estimate the population living within annular regions around each emission source (from 1.0 to 1.5 kilometers away, for example). The exposures experienced by people in this ring-shaped area was then assumed to be the time and direction-weighted average benzene levels for that distance from the sources, as predicted by the air dispersion model discussed above. The risk of leukemia due to benzene exposure was calculated using a linear dose-response model. That is, each unit of exposure to each individual or group of individuals (measured in ppb-person-years) was assumed to induce a similar increase in the number of leukemias that would be produced. The dose-response curve used was obtained from the previously mentioned risk assessment performed by the Carcinogen Assessment Group, and was based on three studies of populations occupationally exposed to benzene. Estimates of the reduction in risk that would be obtained by the various regulatory alternatives, because of the linearity of the dose-response relationship, and also assuming a linear relationship between annual emission rate and average concentrations at a given distance, could be simply accomplished by assuming a proportional reduction in total risk that was equal to the proportional reduction in emissions. A summary of the reductions in the total number of leukemias that are predicted to occur as a result of the regulations of the three types of benzene-emitting facilities is given in Exhibit 4-23.

As stated above, it can be seen that the reductions in total incidence of leukemias for each source class is proportional to the predicted reduction in emissions compared to existing or projected future levels. Given the present level of emissions, it was predicted that benzene exposure from maleic anhydride plants, ethylbenzene/styrene production, and benzene storage facilities would result in the production of approximately 0.45, 0.12 and 0.32 leukemias per year of operations of these facilities.

It should be recalled that there is considerable uncertainty associated with the risk estimate given in Exhibit 4-23 (the sources of this uncertainty will be discussed in more detail below). In addition, the risk estimates given in Exhibit 4-23 are the expected number of leukemias that would be induced per year of operation of the given facilities, not the number of cancers that occur each year, or are occurring now. This is because the induction of cancer by chemical agents generally involves a latency period, which may be years or decades long, between the exposure to the cancer-causing substance and the development of the tumor (or leukemia). Thus any changes in exposure due to emission standards would not result in reduction in cancer risk until years after the regulation went into effect.



## EXHIBIT 4-23

REDUCTIONS IN THE NUMBER OF BENZENE-INDUCED LEUKEMIAS  
BROUGHT ABOUT BY EMISSION STANDARDS

|                                              | Cases of<br>Leukemia/Year<br>of Operation | Percent<br>Reduction |
|----------------------------------------------|-------------------------------------------|----------------------|
| Maleic Anhydride Production                  |                                           |                      |
| Present Control Levels                       | 0.45                                      |                      |
| "97%" Option                                 | 0.066-0.071 <u>a/</u>                     | 85 <u>b/</u>         |
| "99%" Option                                 | 0.047-0.052 <u>a/</u>                     | 92 <u>b/</u>         |
| Butane-for-Benzene Substitution              | 0                                         | 100                  |
| <hr/>                                        |                                           |                      |
| Ethylbenzene/Styrene Manufacturing <u>c/</u> |                                           |                      |
| Present Control Levels                       | 0.12                                      |                      |
| Option A ("85%")                             | 0.038                                     | 68 <u>b/</u>         |
| Option B ("84%")                             | 0.013                                     | 89 <u>b/</u>         |
| Option C ("99%")                             | 0.005                                     | 96 <u>b/</u>         |
| Option D ("100%")                            | 0                                         | 100                  |
| <hr/>                                        |                                           |                      |
| Benzene Storage Facilities <u>c/</u>         |                                           |                      |
| 1980: Present Controls                       | 0.32                                      |                      |
| Various Control Options <u>f/</u>            | 0.32-0.043                                | 0-86 <u>b/</u>       |
| 1985: Present Controls                       | 0.44                                      |                      |
| Various Control Options <u>f/</u>            | 0.44-0.057                                | 0-87 <u>d/</u>       |
| 1990: Present Controls                       | 0.58                                      |                      |
| Various Control Options <u>f/</u>            | 0.58-0.075                                | 0-87 <u>e/</u>       |

a/Depends on number of control failures.b/Compared to 1980 levels.c/Estimates developed by ICF Incorporated assuming a linear relationship between emissions, exposure, and total risk.d/Compared to predicted 1985 levels.e/Compared to predicted 1990 levels.f/A more complete description of the various control options is given in the previous section.



A recent analysis of the maleic anhydride background document by the Regulatory Analysis Review Group (RARG)<sup>2\*</sup> has pointed out that, owing to the high emissions from the Monsanto St. Louis plant and the large population living around the plant, that over 90 percent of the projected reduction in leukemia risks brought about under either regulatory scenario would arise from control of emission from that plant. This leads to a large variance in the cost-effectiveness of the regulation (in terms of health benefits) across maleic anhydride plants.<sup>2\*</sup> It is unlikely that a similar situation exists for either ethylbenzene/styrene production or benzene storage facilities, since there are a large number of facilities with more nearly similar emission rates and control costs.

#### Precision, Accuracy and Limitations of Risk Estimates

In each of the background documents, there is a discussion of the factors affecting the degree of uncertainty associated with risk estimates. In the ethylbenzene/styrene document confidence intervals were placed around the risk estimates by combining the uncertainties surrounding the independent estimates of the amount of exposure and the relationship between the degree of exposure and the increase in leukemia incidence. In the other two documents, the degree of uncertainty surrounding the risk estimates was not estimated quantitatively. The discussion that follows reviews the factors that could contribute to systematic errors and increases in the degree of uncertainty surrounding the risk estimates.

Factors Contributing to Systematic Errors in the Risk Estimates. There are two factors which have the potential for causing systematic errors to be introduced in the population risk estimates: (1) the assumption that individuals receive continuous exposure to the benzene levels predicted by the dispersion models; and (2) the assumption that no one beyond 20 kilometers away from the emission sources receives any exposure to benzene. We expect that the first of these factors, which essentially involves the assumption that the people in the exposed population spend all their time out-of-doors, or that benzene levels indoors are the same as those outdoors, would contribute to overestimation of the total exposure, and hence to overestimation of the leukemia risk. We believe this would be the case because, except for relatively few individuals who work out-of-doors, the vast majority of people in the U.S. spend at least 60 percent of their time indoors. The benzene sources examined here may contribute little to indoor concentration of benzene (although other sources may result in indoor

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<sup>2\*</sup>Regulatory Analysis Review Group, "U.S. Environmental Protection Agency's Proposed Policy and Procedures for Identifying, Assessing, and Regulating Airborne Substances Posing a Risk of Cancer," submitted to the Council on Wage and Price Stability, February 21, 1980.

<sup>2\*</sup>As mentioned in the introduction to this chapter, the Monsanto St. Louis plant is currently installing emission controls. The dominance of this plant in the estimate of benefits will be reduced.

concentrations exceeding outdoor concentrations).<sup>30</sup> If a linear dose-response model is approximately correct, the incremental risk from indoor exposure may be less than the incremental risk from outdoor exposure.

The second analytical assumption, namely, that no one beyond 20 kilometers away from benzene sources experiences any exposure to benzene, seems to have the potential for underestimating total population exposure to benzene, for obvious reasons. This assumption was made because it is known that beyond 20 kilometers, the type of dispersion model used in the risk assessments does not produce reliable results and also that the task of estimating populations exposed increases in magnitude (and expense) with the square of distance. In light of the lack of data about the stability of benzene in the atmosphere and processes which might cause the physical or chemical removal of benzene from the air, it is difficult to say to what extent this assumption actually results in underestimation of exposure. Previous research<sup>31</sup> has suggested that unless there is a great increase in population density beyond 20 kilometers at a large number of sites, the total exposure and risk estimates are not likely to be too greatly affected (less than 50 percent or so) by the decision to cut off the analysis at this point. This is because the estimated benzene concentrations, even in the absence of degradation mechanisms, fall off so rapidly with distance.

Given the lack of data concerning the likely magnitude that each of these analytical assumptions would have on the overall risk estimates, it is difficult to estimate their combined effect on the accuracy of the estimates. It does not appear that a good case can be made for either effect outweighing the other in any consistent fashion. Without further data, we can only make the imprecise statement that these effects seem to cancel each other out, thus not biasing the estimate, but only affecting the precision with which the estimate can be made.

#### Factors Affecting the Degree of Uncertainty in the Risk Assessments.

The factors discussed above have the potential for introducing large systematic errors in the risk estimate for benzene-induced leukemia. Additionally, there are a number of modeling assumptions and data shortages which, at present, cannot clearly be characterized as to their effect on the accuracy of the risk assessments, but do affect the precision that can be assigned to the risk assessments. Most of these factors are discussed in the background documents. These will only be discussed here briefly, with the majority of the discussion reserved for those problems which could seriously affect the precision of the risk assessments, or whose contribution to the uncertainty of these estimates we believe is understated in the background documents.

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<sup>30</sup>Some monitoring data reveal that the contribution of outdoor contamination to indoor levels of contamination is small due to the indoor air exchange properties of buildings with outdoor air and the dispersion properties of pollutants. Additionally, surface adsorption and chemical reactions could tend to purge benzene from indoor air.

<sup>31</sup> Discussion and Critique of . . . , op. cit.

The possible degree of uncertainty in the estimate of emission rates and total emissions has been discussed previously. We noted that there was no reason to suspect that these estimates were biased in any way, and, as we will discuss below, it is not likely that the errors in emission rate estimates contribute in a large way to the uncertainty in the modeling results, compared to other modeling assumptions.

The air dispersion models were also previously discussed, and although they have the potential for contributing much to the uncertainty associated with the final risk assessments, we feel that the major uncertainties which are introduced into the analysis by the air dispersion model have to do with the way these results were interpreted and the procedure that was used to estimate population exposure to benzene. These uncertainties arise from two causes, one recognized in the background documents, the other of which was not recognized. First, the outputs from the air dispersion models, which generated average benzene levels around the various emission sources, produced results that were a function of wind direction, as well as wind speed and emission rates. To obtain average benzene exposure levels, these results which, especially in the case of maleic anhydride plants, were undoubtedly highly asymmetric around the sources, were averaged to produce a single average benzene level at a given distance around emission sources. In a case where the population distribution around emission sources is also asymmetric, this procedure could seriously over or underestimate benzene exposures and hence, the risk of leukemia. Because, on average, for a large number of facilities, we would expect these errors introduced by this procedure to cancel out, we do not expect that any systematic errors were introduced in the total national exposure estimates, only that the degree of uncertainty associated with the exposure estimates is increased.

The second major source of uncertainty in the exposure estimates, not dealt with adequately in the background documents, arises from the use of census estimates of the number of people who live near benzene sources as a proxy for the number of people who experience exposure to benzene. The problem is related to the assumption, discussed previously, that all residents of areas near benzene emission sources experience exposure to benzene 24 hours per day and no one else experiences any exposure. In fact, people move about during the day commuting to school, to work, to shopping, and so forth. If, for example, 65 percent of the adult residents leave the vicinity of benzene emission sources each day to go to work, their exposure for 8 to 10 hours of the day is different (lower, if they work far away from benzene sources) than if they spent 24 hours per day in the vicinity of a benzene source. Similarly, if benzene emission sources are located in industrial areas, where population density is low, but where many people come to work each day, total population exposure could be greatly underestimated by the use of census data. This fact has been recognized in previous attempts to develop estimates of benzene exposure in urban areas,<sup>32</sup> where commuting patterns were taken into account.

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<sup>32</sup>SRI International, Assessment of Human Exposure to Atmospheric Benzene, prepared for the Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, June 1978, EPA 450/3-78-031.



The final major source of uncertainty in the risk estimates arise from the dose-response relationship used to estimate risk from total exposure. The technical difficulties associated with this undertaking have been discussed in great detail elsewhere,<sup>33</sup> and only the most important points will be summarized here.

There are insufficient data to demonstrate, with any degree of certainty, that the increase in risk for any individual or population exposed to benzene is linear with dose. The linear dose-response relationship is simply the best guess that can be made in the absence of more precise data. It should not be thought, as is commonly maintained, that the use of the linear approximation is "conservative", that is, that it tends to overestimate risk. There are a number of hypotheses that support the possibility that increasing exposure to benzene results in either increasing or decreasing increments of risk depending upon the exact mechanism of carcinogenesis. The major point about the linear dose-response model in this case is that failure to consider alternative functional forms for their relationship results in estimates of uncertainty which understate the true range of error in the risk estimates.

The degree of uncertainty in the magnitude of the dose-response relationship is also affected by a number of other factors having to do with the way in which the dose-response model was derived. For example, the epidemiological studies upon which it was based were all studies of populations exposed to concentrations of benzene at least a thousand times higher than those experienced by the general population. Also, the exposures were intermittent, beginning in adulthood, rather than continuous beginning at birth. The study populations consisted almost exclusively of adult males. In two of the three studies used to derive the dose-response relationship, considerable uncertainty exists as to the magnitude of exposure received by the study population, and in no study are any data available as to the actual day-to-day patterns of exposure. All of these problems also contribute to the uncertainty in the overall assessment of risk that have only been partially captured in previous attempts to quantify this uncertainty.

#### Setting Confidence Intervals for the Risk Estimates

In their initial work on benzene, the Carcinogen Assessment Group (CAG) set confidence intervals around their risk estimates for the population risk from exposure to benzene.<sup>34</sup> They assumed that the errors in the parameter relating benzene exposure to leukemia risk were log-normally distributed, as were the errors in the estimates of exposure.<sup>35</sup> Having made these

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<sup>33</sup>Center for Policy Alternatives, Discussion and Critique ..., op. cit.

<sup>34</sup>"Final Report on Population Risk ...," op. cit.

<sup>35</sup>A log-normal distribution is one in which the natural logarithm of the variable in question is normally distributed. A property of the log-normal distribution is that confidence intervals can be expressed as proportions (the median value multiplied or divided by a constant) rather than as a sum (the mean value plus or minus a constant).

assumptions which are reasonable under the circumstances, and having taken into account the variability in the estimates of the magnitude of the relationship between exposure and leukemia risk, the CAG estimated that in the case where the error in the exposure estimates was plus-or-minus 2-fold, the 95 percent confidence interval for risk spanned a range of approximately 7-fold. In the case where the likely error in exposure estimate was 10-fold, the confidence interval for risk was estimated to span a range of about 150-fold about the best estimate.

More recent research, in which the assumptions used to derive the dose-response relationship were extensively evaluated,<sup>36</sup> has suggested that the confidence intervals calculated by the CAG were too narrow. Revised estimates for these confidence intervals were developed, which suggested that, if the exposure estimates could be expected to be accurate within a factor of two, the 95 percent confidence intervals for risks would span a 13-fold range and that if exposure estimates were accurate within a 5-fold range, the 95 percent confidence intervals for risk would span a range of about 48-fold about the best estimate. Assuming that the actual degree of error in the exposure estimates is between two and five-fold, the confidence intervals that can be placed around the risk estimates in Exhibit 4-23 would probably vary between 13-fold and 48-fold about the best estimate.

This has a number of important implications with regard to the usefulness of these estimates in designing and comparing policies. First, while it is obvious that any regulatory strategy that reduces emission for one class of sources will clearly produce a reduction in risk, it is not possible to say with any degree of statistical "certainty" that, in the uncontrolled state, the emissions from any one source class (maleic anhydride plants, for example) actually result in more cases of leukemia per year than any other class (benzene storage tanks). Similarly, it is not clear that more than a few of the regulatory alternatives (for example, the most lenient control scenario for storage tanks and the stringent "99%" option for ethylbenzene/styrene production) can be distinguished one from the other, in terms of the amount of leukemia risk they allow, with any degree of statistical certainty. This implies that, given the state of knowledge and the available data, the present analytical methods, although capable of developing quantitative measures of risk reduction ("effectiveness"), are not capable of distinguishing the differences in effectiveness between policy alternatives that are as similar as the various regulatory alternatives presently being contemplated for control of benzene emissions from maleic anhydride plants, ethylbenzene/styrene manufacturing and benzene storage facilities. Therefore, developing separate measures of effectiveness (in terms of health effects) for each set of regulations would not be a very meaningful exercise.

#### Possibilities for Improving the Analysis

Because a major source of uncertainty in the benzene risk assessment is the uncertainty associated with the dose-response "slope" parameter, it is not

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<sup>36</sup>Center for Policy Alternatives, Discussion and Critique . . ., op. cit.



clear that additional research could improve the precision of the risk assessments sufficiently to enable detailed comparisons between the regulatory alternatives under consideration here and other opportunities for reducing risks to human health. The limiting factor in the precision with which the dose-response parameter can be estimated is the quality of the available data on the actual leukemia incidence in benzene-exposed populations. It is unlikely that the quality of these data will improve in the near future.

There are, of course, same ways in which the quality of the risk estimates could be improved, many of which would be very expensive and time consuming. One could, for example, model the emissions from each individual benzene source, rather than using "model plant" estimates. In addition, dispersion modeling could be performed for each specific point source, using meteorological data from each locality where benzene sources were located. The results of these models could include the actual spatial distribution of benzene exposure, rather than omni-directional average values. For each site, models could be developed to predict the proportion of time that people spend indoors and outdoors and the commuting patterns of residents near benzene emission sources.<sup>37</sup>

Any of these approaches could be used to improve the precision of the exposure estimates. However, as stated above, relatively little would be gained in the way of improved accuracy in risk assessments. Even in the absence of any error in the exposure estimates, for example, it has been estimated that the 95 percent confidence intervals around risk estimates would span a range of approximately 9-fold.

There are several measures that could be taken to help make the risk estimates developed here more useful for comparing these regulations with other regulations affecting risks to the public health. For example, the risk estimates generated here could be used to estimate the total lost life-years among benzene-exposed populations. Such a measure would be useful in comparing the benzene regulations with other regulations which prolong life. Performing such an analysis would require studying the age-incidence patterns of the non-lymphatic leukemias associated with benzene exposure. The resulting time-dependent incidence model could then be used, along with a detailed model for predicting exposure levels (which took into account population mobility and activity patterns) to predict the effect of benzene exposure on leukemia incidence over time. It would then be possible to relate directly the incidence of benzene-induced leukemias to lost life-years, given the demographic composition of the exposed populations. Such a study would also predict the changes in cancer incidence over time brought about by the different regulatory scenarios. If desired, data about the natural history of non-lymphatic leukemias and survival patterns of its victims of the disease could be used to develop measures of reduced morbidity brought about by the regulations.

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<sup>37</sup>EPA is currently developing some site specific models.

#### 4.4 BENZENE NESHAP COST-EFFECTIVENESS ANALYSIS

The cost-effectiveness of the benzene control options can be measured either in terms of dollars per metric ton of emissions prevented or in terms of dollars per leukemia prevented (as mentioned above, however, the estimates of leukemias prevented have wide ranges of uncertainty). Exhibit 4-24 displays the former measure for all the control options. As described in the previous sections, these estimates do not include important costs and benefits such as intermedia effects and the control of other volatile organic compounds. However, using these estimates as the best data currently available, the alternatives can be ranked in order of increasing incremental cost of control, as shown in Exhibit 4-25.

Exhibit 4-25 displays the most cost-effective sequence in which benzene can be controlled by the options examined here. There may be other benzene control opportunities (e.g., petroleum refineries or gasoline distributors) that could enter in this sequence of control options, however, they are not

examined in this analysis.<sup>38</sup> The exhibit highlights several interesting points. Fully half of all estimated emissions reductions is accounted for by control of the maleic anhydride industry. In turn, the maleic anhydride emission reduction is mostly accounted for by two manufacturing locations. Therefore, the accuracy of the total emission and cost estimates is highly dependent on the control requirements at two locations. A more detailed analysis of the compliance costs and emissions at these two plants would be useful.

The divergence between incremental and average cost-effectiveness is also displayed in Exhibit 4-25. As the incremental cost of control climbs to approximately \$2,000 per metric ton of emissions prevented through the first nine control options, the average cost of control is only \$450 per metric ton. The average cost-effectiveness does not reflect the incremental opportunities to reduce emissions, and should not be used as a basis for evaluating the efficiency of a given control option, or for comparing it to other options.

The "incremental versus average" issue highlights the importance of examining more closely the control options in the maleic anhydride industry. The marginal or incremental cost of control may vary significantly within the option of 97 percent control because it is so large. Additional levels of control should be examined (e.g., 80 percent and 90 percent) so that the increments examined are smaller and more nearly equal in size.<sup>39</sup>

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<sup>38</sup>EPA is currently considering some benzene control options that may be more cost-effective than the options analyzed here.

<sup>39</sup>EPA is currently examining additional levels of control.

EXHIBIT 4-24  
COST-EFFECTIVENESS OF VARIOUS BENZENE CONTROL OPTIONS

| Industry                    | Control Option             | Annualized Cost of Control (1,000s of 1980 \$) | Emissions Prevented Annually (Metric Tons) | Average Cost-Effectiveness (\$/Metric Ton) | Incremental Cost-Effectiveness (\$/Metric Ton) |
|-----------------------------|----------------------------|------------------------------------------------|--------------------------------------------|--------------------------------------------|------------------------------------------------|
| <u>Maleic Anhydride</u>     |                            |                                                |                                            |                                            |                                                |
|                             | 97%<br>(carbon adsorption) | 2,125                                          | 5,060                                      | 420                                        | --                                             |
|                             | 99%<br>(carbon adsorption) | 2,850                                          | 5,500                                      | 520                                        | 1,650                                          |
| <u>Ethylbenzene Styrene</u> |                            |                                                |                                            |                                            |                                                |
|                             | 85%                        | (715)                                          | 1,365                                      | (525)                                      | --                                             |
|                             | 94%                        | (245)                                          | 1,790                                      | (140)                                      | 1,100                                          |
|                             | 99%                        | (541)                                          | 1,920                                      | (280)                                      | 310 a/                                         |
| <u>Storage Tanks</u>        |                            |                                                |                                            |                                            |                                                |
| Existing                    | 1                          | 75                                             | 0                                          | --                                         | --                                             |
|                             | 2                          | 45                                             | 200                                        | 225                                        | --                                             |
|                             | 3                          | 1,050                                          | 1,150                                      | 910                                        | 1,060                                          |
|                             | 4                          | 1,730                                          | 1,490                                      | 1,160                                      | 2,000                                          |
|                             | 5A                         | 10,800                                         | 1,520                                      | 7,100                                      | 302,000 b/                                     |
|                             | 5B                         | 10,050                                         | 1,680                                      | 6,000                                      | 43,800 c/                                      |
| New                         | 1                          | 22                                             | 0                                          | --                                         | --                                             |
|                             | 2                          | 110                                            | 640                                        | 170                                        | --                                             |
|                             | 3                          | 280                                            | 760                                        | 364                                        | 1,420                                          |
|                             | 4A                         | 3,570                                          | 790                                        | 4,520                                      | 110,000 d/                                     |
|                             | 4B                         | 3,350                                          | 820                                        | 4,085                                      | 53,000 e/                                      |

a/Incremental control refers to moving from 85 percent control to 99 percent control without 94 percent control as an intermediate.

b/Incremental control refers to moving from control option 4 to control option 5A.

c/Incremental control refers to moving from control option 4 to control option 5B without 5A as an intermediate.

d/Incremental control refers to moving from control option 3 to control option 4A.

e/Incremental control refers to moving from control option 3 to control option 4B without 4A as an intermediate.

EXHIBIT 4-25

BENZENE CONTROL OPTIONS RANKED IN ORDER  
OF INCREASING INCREMENTAL COST OF CONTROL

| Control Option                                            | Incremental<br>Annualized<br>Cost of<br>Control<br>(1,000s of<br>1980 \$) | Incremental<br>Emissions<br>Prevented<br>Annually<br>(Metric<br>Tons) | Incremental<br>Cost-<br>Effectiveness<br>(\$/Metric Ton) | Cumulative<br>Annualized<br>Cost of<br>Control<br>(1,000s of<br>1980 \$) | Cumulative<br>Emissions<br>Prevented<br>Annually<br>(Metric<br>Tons) | Cumulative<br>Average<br>Cost-<br>Effectiveness<br>(\$/Metric Ton) |
|-----------------------------------------------------------|---------------------------------------------------------------------------|-----------------------------------------------------------------------|----------------------------------------------------------|--------------------------------------------------------------------------|----------------------------------------------------------------------|--------------------------------------------------------------------|
| 1. Ethylbenzene/Styrene<br>85% Control                    | (715)                                                                     | 1,365                                                                 | (525)                                                    | (715)                                                                    | 1,365                                                                | (525)                                                              |
| 2. New Storage Tanks<br>Control Option 2                  | 110                                                                       | 640                                                                   | 170                                                      | (605)                                                                    | 2,005                                                                | (300)                                                              |
| 3. Existing Storage Tanks<br>Control Option 2             | 45                                                                        | 200                                                                   | 225                                                      | (560)                                                                    | 2,205                                                                | (250)                                                              |
| 4. Ethylbenzene/Styrene<br>99% Control                    | 174                                                                       | 555                                                                   | 310                                                      | (386)                                                                    | 2,760                                                                | (140)                                                              |
| 5. Maleic Anhydride<br>97% Control<br>(carbon adsorption) | 2,125                                                                     | 5,060                                                                 | 420                                                      | 1,739                                                                    | 7,820                                                                | 220                                                                |
| 6. Existing Storage Tanks<br>Control Option 3             | 1,005                                                                     | 950                                                                   | 1,060                                                    | 2,744                                                                    | 8,770                                                                | 310                                                                |
| 7. New Storage Tanks<br>Control Option 3                  | 170                                                                       | 120                                                                   | 1,420                                                    | 2,914                                                                    | 8,890                                                                | 330                                                                |
| 8. Maleic Anhydride<br>99% Control<br>(carbon adsorption) | 725                                                                       | 440                                                                   | 1,650                                                    | 3,639                                                                    | 9,330                                                                | 390                                                                |
| 9. Existing Storage Tanks<br>Control Option 4             | 680                                                                       | 340                                                                   | 2,000                                                    | 4,319                                                                    | 9,670                                                                | 450                                                                |
| 10. Existing Storage Tanks<br>Control Option 5B           | 8,320                                                                     | 190                                                                   | 44,000                                                   | 12,639                                                                   | 9,860                                                                | 1,280                                                              |
| 11. New Storage Tanks<br>Control Option 4B                | 3,170                                                                     | 60                                                                    | 53,000                                                   | 15,809                                                                   | 9,920                                                                | 1,590                                                              |



Exhibit 4-25 could also be constructed in terms of cases of leukemia prevented per year of operation. In doing so, the cost-effective sequence of control options could change. The order of cost-effectiveness within an industry would not change, but the relative cost-effectiveness across industries could be different from that reported in Exhibit 4-25. For example, upon examination of Exhibits 4-22 and 4-23, we see that under present controls, the number of leukemias per thousand metric tons of emissions varies across the industries as follows:

- Maleic Anhydride: 0.078 leukemias/1,000 metric tons of emissions.
- Ethylbenzene/Styrene: 0.060 leukemias/1,000 metric tons of emissions.
- Storage Tanks: 0.141 leukemias/1,000 metric tons of emissions.

Therefore, it is not equally valuable to prevent a given amount of emissions from each of the industries, and the dollars per metric ton effectiveness measure used in Exhibit 4-25 misrepresents the cost-effectiveness of the control options.

We hesitate to revise Exhibit 4-25 on the basis of predicted health effects because, as discussed above, the estimates of the number of leukemias prevented are very uncertain; the 95 percent confidence intervals for risk may span a range of about 48-fold about the best estimate. Such a large range of uncertainty would erase the distinctions between the estimated cost-effectiveness of the various control options.

Taking into account the fact that portions of the errors of the estimates are correlated improves the usefulness of the data for ranking the benzene control options, although it does not enhance their use in comparison with other regulations. For example, two sources of uncertainty in the estimates of leukemias prevented that have the same underlying true value across all the control options are:

- the dose-response relationship for benzene and leukemia; and
- the potential for benzene related health effects such as chromosome abnormalities, depressions in bone marrow functions, and other types of cancer.

The uncertainty in the estimates caused by incomplete information on these two issues will not affect the relative ranking of the benzene control options. Therefore, the uncertainty is reduced for the purpose of ranking.

It may not be possible to reduce the independent uncertainty of the various estimates sufficiently to accomplish a meaningful ranking. Even if the uncertainty is reduced to five- or ten-fold from forty-eight-fold, the control option ranked second may not be distinguishable from the option ranked ninth (see Exhibit 4-25) because they differ by less than one magnitude (in terms of cancers prevented). Therefore, trade-offs among the top nine control options analyzed here cannot be made very reliably.



## 5. SUMMARY AND CONCLUSIONS

### 5.1 INTRODUCTION

The detailed examinations of the existing EPA lead and asbestos regulations and the proposed benzene regulations highlight several important issues in the performance and use of cost-effectiveness analyses. We have already discussed most of these issues relating to the performance of the analyses and the development of cost and effectiveness estimates in our previous reports prepared for the Office of Toxics Integration.<sup>1</sup> Therefore, these points will only be mentioned briefly. This chapter will focus primarily on several limitations on the usefulness of these types of analyses for regulatory decision-making.

### 5.2 ESTIMATING COST-EFFECTIVENESS

The difficulties encountered in estimating the cost-effectiveness of the regulations examined here are similar to those we have discussed previously. Both costs and effectiveness are often multi-dimensional, thus confounding the quantification of each into single numbers. For example, the costs of the regulations limiting the lead content of gasoline include the usual investment and operating costs, but also include increased crude oil and other energy consumption, changes in the regional distribution of refineries, and the possibility of the closure of certain small refineries or distributorships. A single number reflecting the total social cost of the regulations in most cases cannot be developed. Similarly the problem exists for effectiveness estimates, examples of which can be drawn from each of the three previous chapters.

Effectiveness estimates have the additional problem of requiring a basic set of units in which to be measured. Whereas dollars are the obvious standard of measurement for major components of cost, the major components of effectiveness can be measured in many various types of health benefits, indicators of exposure (such as blood lead levels), ambient concentrations, or emissions quantities. The choice of effectiveness measure is driven by the extent to which the science of the situation is known, and the resources that are available for the investigation.

In our analysis of the benzene regulations we were able to use estimates of reductions in leukemia incidence as a measure of effectiveness. Although the measure of reduced leukemia incidence does not capture all of the

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<sup>1</sup>See ICF Incorporated, Measuring and Comparing the Cost-Effectiveness of EPA Regulatory Efforts to Control Toxics-Related Health Risks--Volume I, Feasibility Study (Washington, D.C.: March 1981, and ICF Incorporated Cost-Effectiveness Review of Six Chlorinated Solvents, draft (Washington, D.C.: 1981).

benefits of the regulation, it does provide a very good approximation for cost-effectiveness analysis purposes since it is a measure of the change in health effects. Similarly, in our analysis of the lead regulations, we used the change in blood-lead levels as a measure of effectiveness. Although not a direct measure of change in health effects, changes in blood-lead levels do provide a surrogate indicator that is as proximate a measure of lead-induced health effects as is currently feasible. In contrast, in our analysis of the asbestos regulations we were forced to rely primarily on measures of tons of asbestos emissions controlled as a measure of effectiveness. In the case of one asbestos regulation, controlling air emissions of asbestos, we also attempted to account for the number of people potentially exposed to the emissions.

In each of these instances the conceptually ideal and "correct" analysis was frustrated by a number of limitations. In the benzene case we found the range of uncertainty underlying the leukemia incidence estimates to be so large that comparisons of the benzene regulations on the basis of the cost per amount of reduced leukemia incidence may not be very meaningful. Similarly confounding problems arose in the lead and asbestos studies. In each case the absence of complete and reliable data, and the lack of reliable models for chronic and acute toxic health effects, demonstrate the limited understanding of the science of the situation. Thus the analyst's ability to provide definitive cost-effectiveness results is likewise limited.

However, cost-effectiveness analysis, as with other analytical techniques, is essentially a tool for organizing, in as rigorous a way as possible, the relevant data, assumptions, and alternatives of each regulatory situation. In a regulatory analysis such as this study has undertaken, the objective of using these analytical techniques is not always to find the definitive solution. Instead, the objective of the analysis is often to systematically organize and compare what can be shown to be the positive and negative outcomes of a regulation, and ultimately to show how these outcomes might change as elements of the regulations, or future regulations and priorities, are changed.

In each of these cases a proportion of the analytical problem can be quantified and manipulated. At a minimum, a measure of the amount of the pollutant that is controlled can usually be reliably quantified. This can be useful information. However, results based on this measure of effectiveness must be used only with caution and an awareness of the remaining elements which are necessary to correlate changes in the amount of pollutant controlled with measurable changes in health effects. To the extent that we can accurately describe or otherwise control for those elements--e.g., ambient concentrations, organism uptake, and populations exposed--then the analyst can draw conclusions regarding the relative efficiency of regulatory alternatives.

Our report discusses the specific problems involved and assumptions required in using the more sophisticated measures of effectiveness. The sections below focus on the limitations to measures of the amount of pollutant controlled, and how these limitations relate to the usefulness of the analysis.

### 5.3 LIMITATIONS IN THE USEFULNESS OF COST-EFFECTIVENESS ESTIMATES

The cost-effectiveness estimates of "dollars per ton of emissions prevented" developed in this report have several important limitations. As mentioned above, the effectiveness measure of tons of emissions prevented does not incorporate information on human exposure and health effects. Therefore, the cost-effectiveness estimates do not necessarily reflect the "true" relative cost-effectiveness of the various pollution control opportunities.

As an example, the analysis of the asbestos NESHAP demonstrates that neglecting the potential for human exposure can have a profound effect on the apparent relative cost-effectiveness of controlling emissions from the asbestos milling and manufacturing industries. The estimated cost per ton for preventing asbestos air emissions from the two industries differed by a factor of seventy ( + 50 percent). However, because the areas surrounding manufacturing locations are more heavily populated than the areas surrounding mills, the consideration of exposure potential reduces the divergence in cost to less than two on a basis of dollars per person-ton of emissions prevented. Furthermore, the uncertainties surrounding the estimates of dollars per person-ton are so large that the control of emissions from manufacturing locations may actually be more cost-effective in terms of reducing total population exposure to asbestos than is the control of emissions from mills. The dollars per ton cost-effectiveness measure does not capture this important aspect of the pollution control opportunities. The dollars per ton figure may even be misleading because the control of asbestos from mills appears to be nearly two magnitudes cheaper per ton than the control of asbestos from manufacturing, which may appear to be large enough to outweigh the uncertainties in the individual cost-effectiveness estimates.

The benzene analysis similarly displays that consideration of exposure potential affects the relative cost-effectiveness of control options. The benzene analysis also shows that when control options are very similar, the uncertainties surrounding the estimates can easily be large enough to prohibit distinctions between the options from being drawn. In Exhibit 4-25 (in which the eleven most cost-effective benzene control options are ranked according to incremental dollars per ton cost-effectiveness) the second and ninth options may be sufficiently similar such that the options may not be reliably ranked within that range.

The asbestos analysis also demonstrates the importance of considering differences in the types of human health effects likely to result from exposure to the pollutant being controlled. The human health effects of exposure to asbestos in air are fairly well known and have been characterized as asbestosis, restrictive pulmonary dysfunction, and cancer (including lung cancer and mesothelioma). The effects of asbestos ingestion from water are less well known and have not been specifically characterized to date. Comparison of the dollars per ton cost-effectiveness estimates for the asbestos NESHAP and effluent guidelines obscures these important differences in the likely effects of reducing emissions. Some of the major limitations in using the dollars per ton cost-effectiveness measure are summarized in the following sections.



### 5.3.1. Intramedia Comparisons of Individual Substances

Of the various possible uses of dollars per ton cost-effectiveness analyses, this is probably the most promising. Keeping comparisons within a single medium for a single substance often eliminates potential differences in expected health effects from controlling the various sources. Also, the largest uncertainties, which often relate to the dose-response relationship, persistence of the substance, and certain dispersion characteristics of the substance, will be common to all the control options so that these uncertainties will not affect the relative cost-effectiveness of the emission reduction opportunities.

The primary short-fall of using dollars per ton for these comparisons is the lack of consideration for exposure potential. The asbestos analysis demonstrates one method for handling this problem. A moderate amount of additional investigation could probably result in a meaningful comparison of the cost-effectiveness of controlling asbestos air emissions from the milling and manufacturing industries on the basis of dollars per person-ton of emissions prevented. A similar approach could be used in the benzene analysis; however, the benzene control options are so similar that the remaining uncertainties would probably be large enough to prohibit a meaningful ranking of the control options. Overall, intramedia comparison of individual substances on the basis of dollars per ton of emissions prevented can be useful if the potential for exposure is also considered.

### 5.3.2 Intramedia Comparisons Across Substances

Dollars per ton cost-effectiveness comparisons across substances within a single medium are much less reliable than comparisons for single substances. The lack of information on exposure potential remains a problem and its solution is complicated by the fact that the substances may have very different persistence and dispersion properties. It would not be sufficient to estimate the number of people in annular regions around the various major sources of emissions as was done in the asbestos analysis. The potential population at risk from each substance would probably have to be estimated separately.

There are other problems involving making comparisons across substances. For a single substance the non-quantified aspects of costs and benefits are more likely to be similar and comparable than for examinations of cost-effectiveness across substances. The substitution and inter-media effects caused by the control of the various substances can vary widely. For example, controlling benzene tends to control other volatile organic compounds under most of the control options. Although not specifically quantified, this added benefit is present in almost all the cost-effectiveness comparisons of benzene, and is therefore balanced out to a great extent. Controlling asbestos air emissions also controls other particulate emissions. Again, this added benefit is not quantified but is present in comparisons between asbestos control options. These unquantified aspects of the control options can significantly affect comparisons made across substances because they will not be present in all the control options being considered, for example in comparison between control options for benzene and asbestos air emissions.

Perhaps the most obvious complication of comparing across substances is differences in health effects caused by exposure to the various substances. To adequately address this problem, a full risk assessment relating emissions to specific health effects in the population is required. However, this defeats the purpose of developing the simpler and more convenient cost-effectiveness measure of dollars per ton. Also, as is the case with lead in air and asbestos in water, there is often large uncertainties in the medical evidence upon which estimates of health benefits are based. Therefore, the value of partially quantifying uncertain health effects may not warrant its expense, and instead an appreciation of the differences in severity of the expected health effects may be sufficient. This, of course, depends on many factors other than the choice of cost-effectiveness measures to use, and should be examined in the context of the overall agency strategy for regulating toxic substances in the environment.

Overall, dollars per ton of emissions prevented is not very useful for comparisons across substances within a single medium. If the physical properties and potential health effects of the substances vary significantly, then much more detailed exposure and risk data are required for meaningful analyses. However, the uncertainties in the individual exposure and risk estimates will not be correlated (as they are when comparisons are made between control options for a single substance) so that the additional analysis may often yield inconclusive results.

#### 5.3.3 Intermedia Comparisons of Individual Substances

Intermedia comparisons of individual substances can have all the problems of intramedia comparisons across substances and more. If the properties of a substance vary significantly across media, e.g., from air to water, then the comparisons are actually being made between two "different" substances. Additionally, the route of human exposure may vary, e.g., inhalation versus ingestion, which will necessitate detailed exposure estimates. The asbestos analyses demonstrate that comparisons of estimates of dollars per ton of emissions prevented for the NESHAP and effluent guidelines are not reliable rankings of cost-effectiveness of the various control options.

There may be situations in which these intermedia comparisons closely resemble intramedia comparisons of single substances. For example, some solvents in water effluent volatilize quickly and enter the air. In this case, water effluent can be easily compared to air emissions on the basis of dollars per ton of emissions prevented. As mentioned earlier, exposure potential would have to be considered.

#### 5.3.4 Intermedia Comparisons Across Substances

The cost-effectiveness measure of dollars per ton of emissions prevented is least useful for intermedia comparisons across substances. The dollars per ton figures do not reflect important differences in exposure route and potential, and differences in health effects. All the confounding factors listed above come together to make these estimates potentially misleading for comparisons of this type.



Unfortunately, a simplified cost-effectiveness measure (such as dollars per ton) is most desirable in complex situations involving control options of many different substances in various media. A uniform, easily obtainable measure would facilitate initial priority setting and decision-making that could be fine-tuned with more specific information obtained later on. The fact that such a measure falls short of providing adequate information on the relative cost-effectiveness of control options highlights the complexity of integrating the control of toxics across media. The dollars per ton estimates may provide some assistance in the solution to these problems. Exhibit 5-1 summarizes the limitation on using dollars per ton as a cost-effectiveness measure.

#### 5.4 SUMMARY

Cost-effectiveness as measured in dollars per ton of emissions prevented has limited uses and must be used with caution. Its strengths and weaknesses are basically one and the same; namely, that very little effort is expended on problematic questions of exposure and health risk. This is a strength because it greatly reduces the complexity and resource intensity of the analyses. This is also a weakness because it excludes important information required for decision-making and may produce misleading results. As discussed above, the primary usefulness of this approach is in the comparison of control options for a single substance all within the same medium. In some situations, dollars per ton of emissions prevented, when interpreted properly, can be helpful in analysis of alternative regulatory options.

## EXHIBIT 5-1

SUMMARY OF MAJOR LIMITATIONS ON USING "DOLLARS PER TON"  
AS A COST-EFFECTIVENESS MEASUREComparison Type

|                 |                   | Single Medium                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Across Media                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|-----------------|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Comparison Type | Single Substances | <ul style="list-style-type: none"> <li>• Lack of consideration for exposure potential including differences in population at risk</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                  | <ul style="list-style-type: none"> <li>• Lack of consideration for exposure potential including:               <ul style="list-style-type: none"> <li>--differences in exposure route;</li> <li>--differences in population at risk; and</li> <li>--differences in persistence and dispersion properties</li> </ul> </li> <li>• Lack of consideration for differences in health effects.</li> <li>• Lack of consideration for differences in unquantified aspects of costs and effectiveness.</li> </ul>                                                           |
|                 | Across Substances | <ul style="list-style-type: none"> <li>• Lack of consideration for exposure potential including:               <ul style="list-style-type: none"> <li>--differences in population at risk</li> <li>--difference in persistence; and</li> <li>--differences in dispersion properties</li> </ul> </li> <li>• Lack of consideration for differences in health effects.</li> <li>• Lack of consideration for differences in unquantified aspects of costs and effectiveness.</li> <li>• Large uncorrelated uncertainties in estimates.</li> </ul> | <ul style="list-style-type: none"> <li>• Lack of consideration for exposure potential including:               <ul style="list-style-type: none"> <li>--differences in exposure route;</li> <li>--differences in population at risk; and</li> <li>--differences in persistence and dispersion properties</li> </ul> </li> <li>• Lack of consideration for differences in health effects.</li> <li>• Lack of consideration for differences in unquantified aspects of costs and effectiveness.</li> <li>• Large uncorrelated uncertainties in estimates.</li> </ul> |